DESIGN AND FABRICATION OF BAMBOO COMPOSITE DOOR FOR THREE WHEEL VEHICLE IN ETHIOPIA

By : Mulugeta Denanto

A thesis submitted in partial fulfillment of the requirement for the award of the degree of

Master of Science

in

Automotive Engineering

MECHANICAL ENGINEERING DEPARTMENT

School of Mechanical, Chemical and Materials Engineering

ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

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Approval Sheet

Approved by Board of Examiners

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CANDIDATE'SDECLARATION

This is to certify that the thesis prepared by Mulugeta Denanto, entitled: **Design & Fabrication of Bamboo Composite Door for Three Wheel Vehicle in Ethiopia**; here by declare this thesis is my original work and that it has not been submitted in full for a degree in any university/institution, which compiles with the regulations of the university and meets the accepted standards with respect to originality and quality.

Mulugeta Denanto Shote (Candidate)

Signature ___________________

Date____________________

This is to certify that the above declaration made by the candidate is correct to the best of my knowledge.

Advisor: Mr. Mekonnen Liben (Asst. Prof) Signature ______________ Date_______________

Co-Advisor: _____________________ Signature _______________ Date_______________

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List of Acronyms and Abbreviations

AIJRSTEM: American International Journal of Research in Science, Technology, Engineering and mathematics

ASTM: America Society for Testing and Material

BFREC: Bamboo Fiber Reinforced Polyester Composite

EACE: Ethiopia Assessment and confirmative Enterprise

IJERT: International Journal of Engineering Research & Technology

IJMET: International Journal of Mechanical Engineering and Technology

NFRC: Natural Fiber Reinforced Composites

ULSTAB: Ultra-light Steel Auto Body

UTM: Universal Tensile Machine

ABSTRACT

The car door is one of the important components which can be used as protection and safety for passengers in case of accidents and collisions. Side impact crashes can be normally risky because of the fact that there may be no room for massive deformation to protect an occupant from the crash forces. The component effect collision is the second biggest cause of death. Day through day, the growth of the fuel price and the emission of the smoke from the vehicles are also the fundamental issues in the current-days worldwide; in general; the safety, fuel performance and emission laws of the passenger cars are crucial issues inside the modern-day global. Reinforcement with natural fiber in composites has recently gained attention due to low cost, low density, acceptable specific properties, ease of separation, enhanced energy recovery, CO_2 neutrality, biodegradability and recyclable nature. The objective of this thesis is to design and fabrication of three-wheeler Bajaj door panel using bamboo fiber reinforced polyester composite materials. To achieve the objectives set, design and fabrication of the component and experimental methods are employed. For this thesis work a raw material selected is bamboo plant. The woven bamboo fiber strip which has been taken as reinforcement and the matrix material (polyester resin) and hardener in this study was purchased from local market. The chemically treated bamboo strip fiber by 5% NaOH with distilled water of 95% applied to purify the bamboo fiber. E- Glass fibers were mixed with polyester resin by simple manual stirring for 15minutes and the mixture was poured into the moulds, keeping in view the requirements of various testing conditions and characterization standards. The composite samples of Bamboo fiber was prepared in three different orientation (0°, 90° and 0/90°).The part might require 0° plies to react to axial loads, ±45° plies to react to shear loads, and 90° plies to react to side loads. According to the samples analysis results, 0° orientation was selected for this thesis model. Because the strength design requirements are a function of direction of the applied load. Based on the tensile, compression, bending analysis and water absorption properties, experimental data study results it was found 160MPa(0°), 2709.2MPa(90°), 110N (0/90°) and 4% respectivly. The door panel of three wheel Bajaj vehicle was used to develop the geometric model of the door panel by CATIA V5 modeling software. Based on these results, it is recommended that bamboo fiber reinforced with polyester composite materials with strength of 160MPa is suitable for new external structural automotive door panel of three- wheel Bajaj compact 205 model type applications.

Key words: Bamboo fiber, Polyester, composite, door panel, Bajaj vehicle, Natural fiber

CHAPTER ONE

1. INTRODUCTION

1.1 Background of the study

It is a natural phenomenon that human beings keep on moving here and there to perform their day to day activities within a given time range; and vehicles are the dominant way of transportation system in many countries, including Ethiopia. Thus, researching on these area to design and provide a well improved, fast, economic and aesthetically attractive vehicles is a crucial idea for the development of these countries by providing fast, effective and sufficient way of transportation. To address this aim a wise material improvement and design excellency are crucial mechanisms.

In Automotive - Composites are being considered to make low weight, safer and more fuel-efficient vehicles. A composite is composed of a high strength fiber (carbon or glass) in a matrix material (epoxy polymer) that when combined provides magnify properties compared with the individual materials by themselves. Determining the right material during the selection process is very important. The material selected should meet the expectation of the engineer. The material should be mechanically feasible and should have low cost. Other than the manufacturing of bumpers, the composite materials have a wide range of other potential automotive applications such as body panels, suspension, steering, brakes and other parts of the automobile. Apart from body panels, the current, limited automotive application of composites include bumper systems, leaf springs, drive shafts, fuel tanks, instrument panels, cross wheel beam, intake manifold [1].

Moreover their aesthetical appearance should be upgraded by researching materials for this application too. A number of researches have been demonstrated that composite materials are lightweight, fatigue resistant and easily molded to any shape, in other words, a seemingly attractive alternative to metallic materials.

If the benefits of composite materials in terms of light weighting, durability, good aesthetical value, high specific energy absorption ability and ease of forming are to be exploited more widely by the automotive industry, then there is a need to identify the critical technical barriers that must be overcome[3,9].Applications of composite materials in automotive industries already include some structural parts, such as dashboard, roof, floor, front & back bumper, passenger safety cell, and door panels [10,15].The door panel of an automobile is typically made up of a variety of materials among which composite material is one. Composite materials may be made of natural fibers and polymer matrix with synergistic properties, improving their strength and durability. These materials are suitable for achieving automotive outer components, where in addition to their low weight have also high rigidity and good thermal and sound insulation. The most important outer vehicle elements include car outer door panels [2].

Nowadays, substitution of conventional materials such as steel, aluminum and other alloy materials with composite materials has grown significantly in aeronautic, automotive, naval, and civil construction sectors. This is due to their amazing properties, i.e. Composite materials have of high modulus to weight ratio and strength to weight ratio, excellent fatigue properties, and non-corroding behaviors. These advantages encourage the extensive application of composite materials in different areas including automotive industries [15].

Traditionally, the materials used in the construction of vehicle bodies are mainly various grades of steel and aluminum. Moreover, plastics and some synthetic materials mostly dominate the vehicle interior parts. The manufacturers meet the requirements of a particular crashworthiness standard and fuel efficiency by making the approximate design change in their vehicle structure and by introducing necessary structural components that satisfy the overall design objectives [4]. With the composite materials the designer can vary structural parameters, such as geometry and at the same time vary the material properties by changing the fiber orientation, fiber content. These properties of the composite materials create the positive environment in automobile industries, since they provide required strength for less weight when compared to steel and aluminum [9, 10].

1.2 Problem Statement

The demand of transportation system is increasing in a dramatic manner in our country, Ethiopia. To meet these needs the automotive industries in Ethiopia import the spare parts from abroad. But if these spare parts can be replaced by lightweight, inexpensive and locally available materials, we can improve the vehicle performance and simultaneously save foreign currency for imported one. Thus, bamboo which is the abundant resource in Ethiopia can be the suitable material for manufacturing the external door panel of compact model 205 three wheel.

Three wheel vehicles are one of India's largest companies product, making motorcycles, scooters, three-wheeled auto-rickshaws, and most recently, automobiles. The motor and chassis are imported to Ethiopia, but the final vehicle itself is assembled in Mekelle & Adama.

There is a frequent accident occurring on three wheelers which have made users lose their confident to be served by these vehicles; the main reason is the safety issue, i.e. absence of protection door panel and if fit they are of poor strength. Hence, this thesis work is focused on fabricating new door panel structure from reliable composite materials which can solve the users problem. Therefore, this thesis focuses on solving of this problem which is observed in a three wheelers by design and fabrication of a reliable door panel from a reliable material.

1.3 Objective of the Study

1.3.1 General Objective

The general objective of this thesis work is to design and fabricate new door panel for three wheeler vehicle from bamboo fiber composite material.

1.3.2 Specific objectives

The specific objectives of this thesis work are to:

- ✓ Collect data about the existing door panel.
- ✓ Determine the fiber orientation and fabricate composite.
- ✓ Test strength of the bamboo composite material.
- ✓ Model the door panel using CAD software.
- ✓ Prepare the bamboo composite door panel
- ✓ Compare the strength of existing and newly designed door.

1.4 Significance of the Study

Composite typically use some type of fiber to reinforce the material and improve the properties. Bamboo fiber-reinforced composites introduce a very stiff material into a very flexible polymer matrix. The polymer holds the bamboo fiber together in a way that it would not be able to be on its own. The properties are tunable too, so with a higher volume fraction of polymer, we can get a more elastic material. Bamboo composite material applied as door panel is expected to be of:

- ❖ High stiffness and better mechanical strength

- Less noiselower Vibration than metals
- Adaptable property than metals
- Long life extending: excellent fatigue, impact, environmental resistance resulting in reduced maintenance
- Reduced life cycle cost when compared to metallic materials
- Excellent corrosion resistance and fire retardant.

1.5 Beneficiaries

Automotive industries, vehicle owners, society, researcher and the country as a whole will be advantageous from this thesis work.

1.6 Scope of the Study

The scope of this work includes the preparation of composite material from bamboo fiber reinforced polyester, fabrication of door panel, testing for strength of the door panel, modeling and analysis using
software, comparison of the existing door panel with the newly designed, and finally preparation of prototype door panel.

Organization of the study

The study is organized in the following chapters:

- Chapter one: Introduction-. In the first chapter background, statement of the problem, motivation of the research, objectives and methodology of the study are discussed.
- Chapter two: Literature review - The journals, articles and publications that are related to this research work are reviewed.
- Chapter three: Materials and methods- materials used, the conditions and the methods of analysis are stated, Conceptual design, Simulation and drawing.
- Chapter four: Results and discussion- results are displayed and an appropriate discussion is done.
- Chapter five: Conclusion, Recommendation and future work of the research are stated.

CHAPTER TWO

2 LITERATURE REVIEW

2.1 Introduction

The design of vehicle body has evolved from a simple, all steel structure that meets the basic requirement of strength and functionality, to the current day complex and efficient structure. Lightweight composite materials have been used to replace conventional one. This is because composite materials offer significant opportunities for enhancement of product performance in terms of strength, stiffness and energy absorption, combined with weight reduction & space saving. There are many journals, articles, thesis papers, books, conference and published study in the world related to automotive body structure materials and their analysis. These previous works were trying to address different approaches to design and analyze the automotive body parts by using different materials (conventional and composite).

Natural fibers have become popular reinforcement material for fiber reinforced polymer composite developments. The reinforcement can replace the conventional fiber, such as glass, aramid and carbon as an alternative material [20].

The main advantageous of natural fibers include low cost, fairly good mechanical properties, high specific strength, non-abrasive, & eco-friendly. In spite of impressive specific mechanical properties, the main challenges associated with these reinforcements include severe moisture absorption, fire resistance, mechanical properties and durability, variability, and manufacturing/processing of natural fiber reinforced plastic composites [30].

2.2 Composite Materials

Composite material is a multi-phase combination material of two or more component materials with different properties and different forms through compounding processes, it not only maintains the main characteristics of the original component, but also shows new character which are not possessed by any of the original components. Composite materials should have the following characteristics: microscopically it is non-homogeneous material and has a distinct interface; there are big differences in the performance of component materials; the formed composite materials should have a great improvement in performance; the volume fraction of component materials is larger than 10%. According to this definition, composite materials in a wide range of areas, straw mud wall, steel bar reinforced concrete, and tire cord, etc. all belong to the scope of composite materials.

From analysis of the composition and the internal structure of composite materials we found that it includes three basic physical phases. One is called matrix phase which is continuous, another is called reinforcement which is scattered and surrounded by the matrix. The other is called composites' interface which is an interface between reinforcement phase and matrix phase. For further study on micro-structure level, we found that, owing to the complex physical and chemical reasons in compounding process, the reinforcement phase and the matrix phase near the interface become a complex structure which is different from both of the matrix phase and the reinforcement phase of their own. And at the same time, we found that the structure and morphology have an impact on macroscopic performance of composites, so the microscopic area near the interface changes in structure and properties. Thus it becomes the third phase of composites, which is called interphase. Therefore, composite material is composed of matrix phase, reinforcement phase and interphase. The structure and the nature of these three phases, their configuration and interaction, as well as the relative content determine the performance of composite materials.

Bamboo can be used as reinforcement material of composite in various forms, such as bamboo powder, bamboo strips [13], bamboo fibers [11], bamboo fabrics and bamboo woven mat [12]. A laminate composite consisted of polyester resin as the matrix and bamboo woven mat as the filler. Bamboo strips are reported having higher cohesive strength among different types of bamboo form [14]. It is expected that the use of bamboo as reinforced of polymer matrix will produce composites materials with better properties in specified applications. Bamboo polymer composites can consist of either a thermoplastic or thermoset matrix which binds the fibers together.

Composite materials discussed in modern materials science are generally referred to as fiber, sheet, and particle reinforced, or self-reinforced polymer matrix, ceramic matrix or metal matrix composites. This definition grasps the essence of the composite materials, namely the enhancing concept by enhancer.

2.3 Classification of composite materials

Different criteria's are taken in to account to classify Composite materials. The fiber arrangements and the types of matrix materials used in a composite can be considered.

2.3.1 Fiber arrangement

The fiber arrangement and its orientation within the composite is varying from one composite material to the other during manufacturing process. This variation helps the manufacturer to get a material with different properties. On the bases of fiber orientation and arrangement, composite materials can be classified as follows.

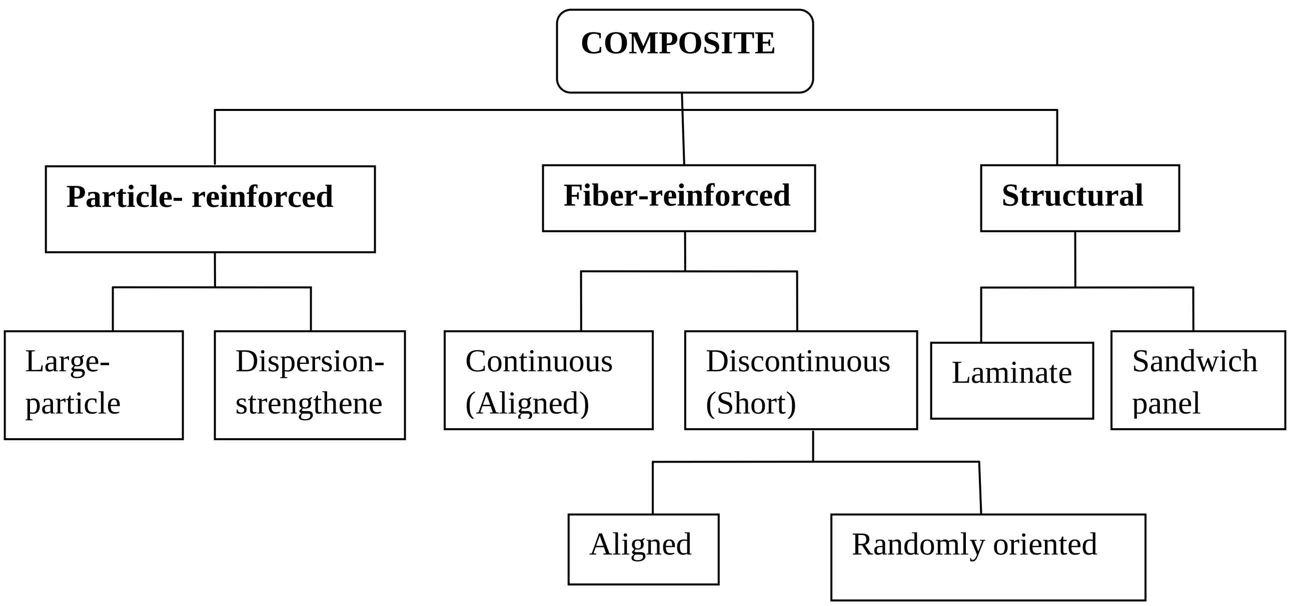


Figure 2.1: Composite materials classification based on fiber orientation

2.3.2 Particle-reinforced composite

The role of reinforcement in composite materials is primarily to add mechanical properties to the material such as strength and stiffness. Thus, particles are used to increase the modulus of the matrix, to decrease the permeability of the matrix, or to decrease the ductility of the matrix. [13].

Some representative particle reinforced composites are shown as under in Figure 2.3.

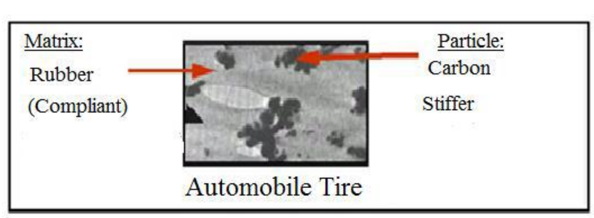
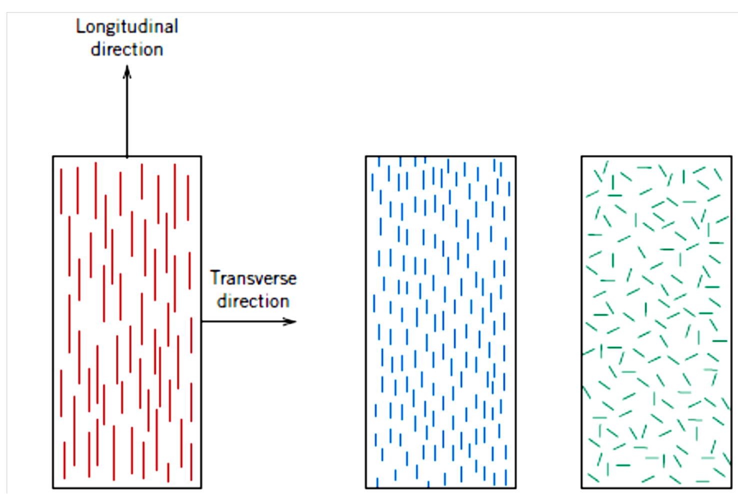


Figure 2.2: Particle reinforced composite [13].

2.3.3 Fiber-reinforced composites

Fiber reinforced composites provide improved strength, fatigue resistance and strength to weight ratio over the constituent materials. Reinforcing fibers are responsible to increase the modulus of the matrix material in the composite. The strong covalent bonds along the fiber's length give them a very high modulus in this direction because to break or extend the fiber the bonds must also be broken or moved.

The arrangement or orientation of the fibers relative to one another, the fiber concentration, and the distribution all have a significant influence on the strength and other properties of fiber-reinforced composites.



Continuous and aligned, discontinuous and aligned, and Discontinuous and randomly oriented fiber reinforced composites respectively.

Figure 2.3: Fiber reinforced composites [13]

2.3.4 Structural composites

A).Composite Laminate

Laminates are sheet constructions which are made by stacking layers (also called plies or lamina) in a specified sequence. The layers are often in the form of „prepreg" (fibers preimpregnated with partly cured resin) which are consolidated in an autoclave. A laminate may have more than 4 layers and the fiber orientation changes from layer to layer in a regular manner through the thickness of the laminate. The figure shown below describes how the laminate is formed from the ply or lamina [15].

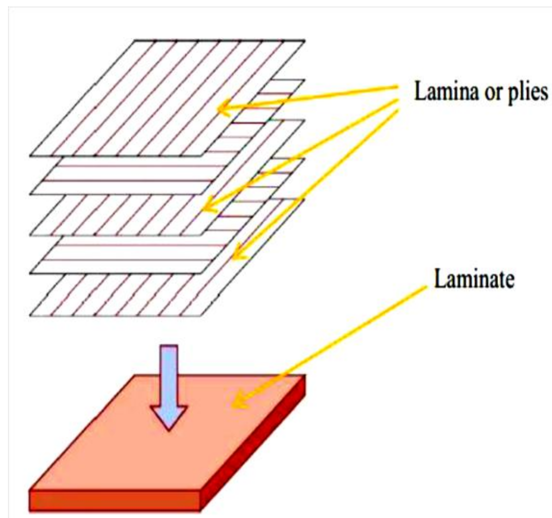
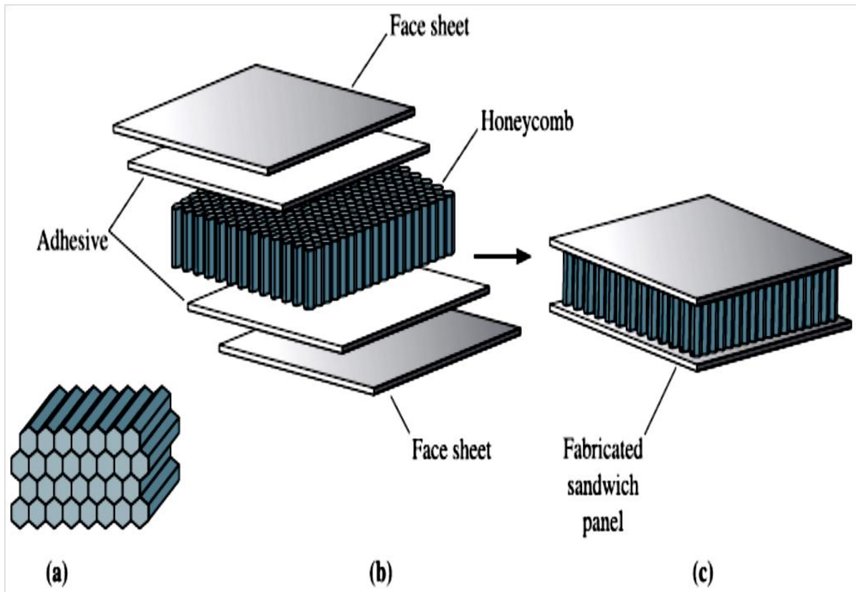


Figure 2.4: Composite laminate [15]

B).Sandwich panels

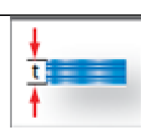
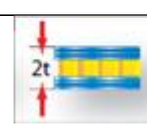
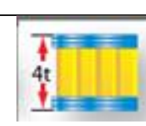
Composite polymer matrixes have low density, honeycomb core as a reinforced bonded with the face sheet matrix by adhesive layers. Sandwich panels have the benefits of light weight, large bending stiffness and energy absorption [12, 13].



(a) A hexagonal cell honeycomb core (b) can be joined to two face sheets by means of adhesive sheets, (c) producing an exceptionally lightweight yet stiff, strong honeycomb sandwich structure.

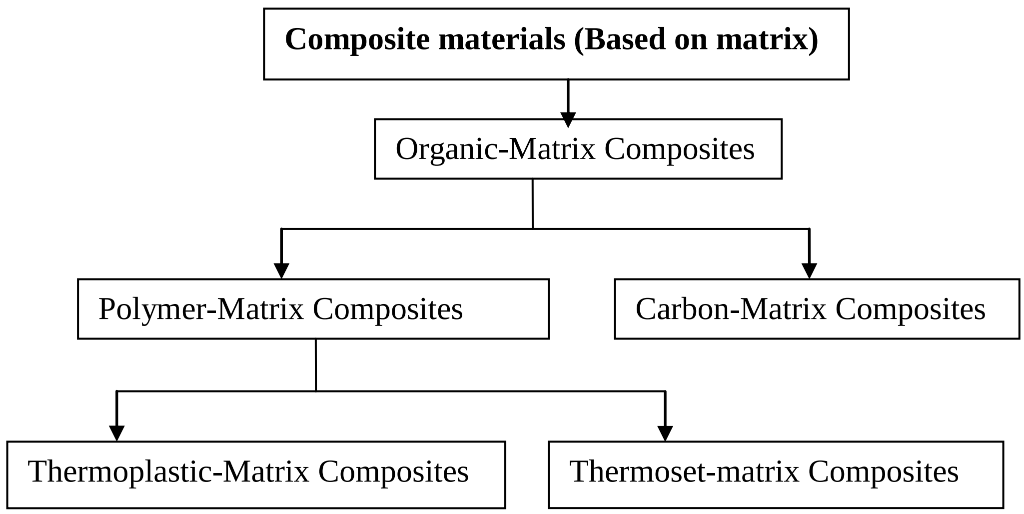
Figure2.5: Sandwich constructions with honeycomb core.

Table 2.1: Strength and stiffness of honeycomb sandwich material compared to a solid laminate [12, 13]

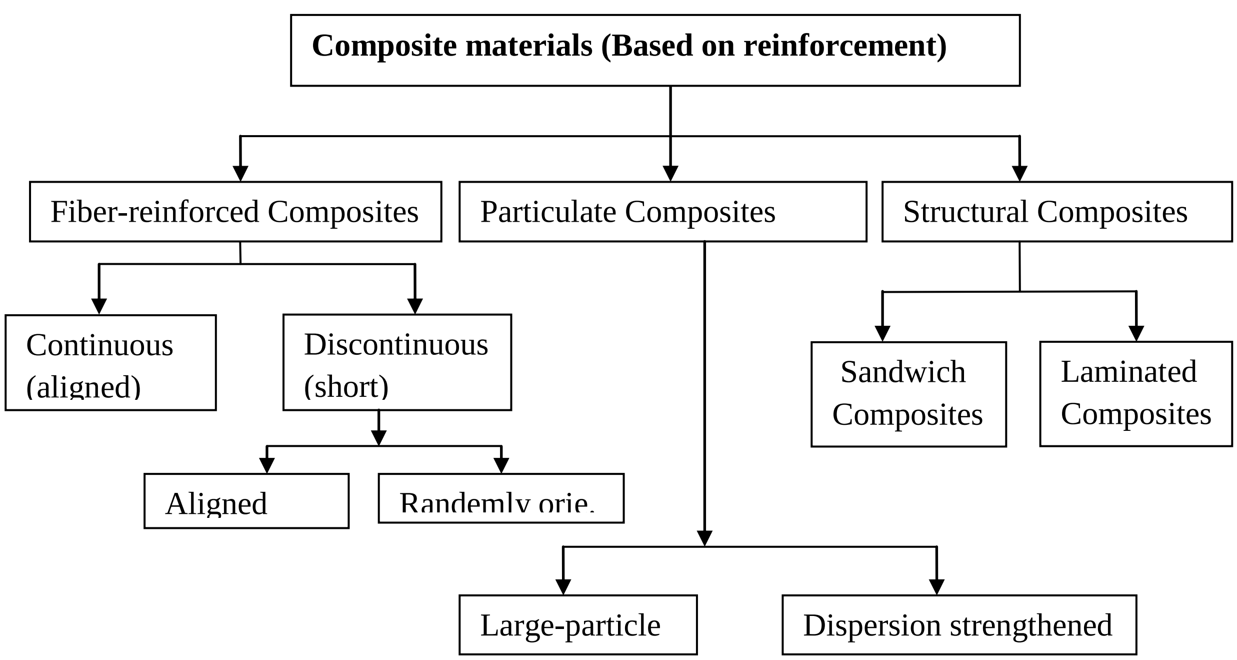
	SOLID MATERIAL	CORE THICKNESS t	CORE THICKNESS 3t
			
Thickness	1.0	7.0	37.0
Flexural Strength	1.0	3.5	9.2
Weight	1.0	1.03	1.06

Matrix materials

Another way of classifying composite materials is focusing on the type of its matrix component of the composite. Based on this measurement, composite materials can be arranged as the following chart shown below:



(a)



(b)

(a) Based on matrix materials and (b) based on reinforcement materials

Figure 2.6: Classification of composite materials.

2.3.5 Characteristics of the composites

Composites consist of one or more discontinuous phases embedded in a continuous phase. The discontinuous phase is usually harder and stronger than the continuous phase and is called the 'reinforcement' or 'reinforcing material', whereas the continuous phase is termed as the 'matrix'. Properties of composites are strongly dependent on the properties of their constituent materials, their distribution and the interaction among them. The composite properties may be the volume fraction sum of the properties of the constituents or the constituents may interact in a synergistic way resulting in improved or better properties. Apart from the nature of the constituent materials, the geometry of the reinforcement (shape, size and size distribution) influences the properties of the composite to a great extent. The concentration distribution and orientation of the reinforcement also affect the properties. The shape of the discontinuous phase (which may by spherical, cylindrical, or rectangular cross-sectioned prisms or platelets), the size and size distribution (which controls the texture of the material) and volume fraction determine the interfacial area, which plays an important role in determining the extent of the interaction between the reinforcement and the matrix. Concentration, usually measured as volume or weight fraction, determines the contribution of a single constituent to the overall properties of the composites. It is not only the single most important parameter influencing the properties of the composites, but also an easily controllable manufacturing variable used to alter its properties.

2.3.6 Components of a composite material

In its most basic form a composite material is one, which is composed of at least two elements working together to produce material properties that are different to the properties of those elements on their own. In practice, most composites consist of a bulk material (the 'matrix'), and a reinforcement of some kind, added primarily to increase the strength and stiffness of the matrix.

Matrix: Matrix is a material which holds the fibers together. It protects the fibers from environment and abrasion with each other. Matrix distributes the loads evenly between the fibers. It helps to maintain the distribution of fibers and provides better finish to final product. In the experiment polyester resin is used as a matrix material.

Polyester resin (EP): Polyester resin has wide range of industrial applications because of their high strength and mechanical adhesiveness characteristic. Araldite CY-230 is a liquid solvent free polyester resin. Curing takes place at atmospheric pressure and room temperature after addition of hardener. Generally, curing shrinkage is very less and may further be reduced by the addition of fillers such as bio-particles, China clay etc. The resin can be easily colored. Mechanical, electrical properties and higher resistance to chemical and atmospheric attack of fully cured mixture are excellent. Ageing characteristics of the castings are good. Resin can be stored for at least a year if they are stored under cool, dry conditions in the original containers. Polyester is also good solvent and it has good chemical resistance over a wide range of temperature [13].

Polyester resins– used for manufacture of huge and massive elements that are not required to meet some special requirements regarding construction. As much as 90 % of products in our domestic market have been manufactured from polyester resins (polyester composite) and only 10 % from epoxy resins (epoxy composites).

Unfortunately, because polyester resins are half the price, they often find applications in the manufacture of products that actually should be made from other materials (e.g. intake tubes, motorcycle parts, carbon fiber hoods, carbon fiber composites etc..).

/Hardener: Hardener is used to cure the polyester resin. Generally, it is mixed with polyester resin at normal atmospheric temperature. Polyester resin is cured by mixing it with hardener in equal amounts. Hardener is available in liquid form. When polyester resin and hardener are mixed together, chemical reaction takes place and because of which, mixture starts to harden.

Reinforcement: The role of the reinforcement in a composite material is fundamentally one of increasing the mechanical properties of the neat resin system. All of the different fibers used in composites have different properties and so affect the properties of the composite in different ways. For most of the applications, the fibers need to be arranged into some form of sheet, known as a fabric, to make handling possible. Different ways for assembling fibers into sheets and the variety of fiber orientations possible to achieve different characteristics. Desirable properties in a composite, the applied load should be effectively transferred from the matrix to the fibers via the interface. This means that the interface must be large and exhibit strong adhesion between fibers and matrix. Failure at the interface called de-bonding may or may not be desirable.

Reinforcing element, the addition of reinforcing agents to the resin improves the properties of the material. Bamboo fibers are used as reinforcing agents to improve the different properties of the composites material.

2.4 Bamboo Plant and its fiber

Bamboo is a composite material of cellulose fibers, with an average tensile resistance of about 700 MPa [17]. These cellulose fibers are immersed in a lignin matrix. Studies showed that bamboo is a material with the variation of its physical and mechanical properties in an optimized form, according to the stresses generated due to wind load and its own weight. It has been observed on a macroscopic scale that the distances between the nodes (stiffeners), the diameter and the thickness vary along the total length of the bamboo Culm.

Figure 2.7: Bamboo Plantation

The strength of bamboo culm is made up from numerous bamboo fibers aligned longitudinally along its length. Bamboo fibers form bundles, which are components of vascular bundles dispersed within the diameter of the culm. Several studies on the microstructure of bamboo culms identified that there are certain trends in the distribution of vascular bundles within the diameter and along the length of the culm. The size of vascular bundles is smaller at the outer section, near the epidermis of the culm and bigger at the middle, near the hollow part. The concentration of vascular bundles increases from the middle to the outer part of the culm. Vertically, the size of vascular bundles decreases from the bottom to the top with increasing percentage of fiber bundles. However, ageing does not affect the percentage of fibers significantly [17].

All lignocellulosic natural fibers can be considered as composites, as they consist of cellulose microfibrils in an amorphous matrix of lignin and hemicellulose. Bamboo fibers have a considerably high percentage of lignin compared with other natural fibers, resulting in its high strength. Stronger fibers form stronger culm structures. However, excess lignin hinders the extraction process, meaning the separation of individual fibers. Lignin remaining on the fiber surface after extraction creates strong but brittle fibers [18].

2.4.1 Bamboo Plants in Ethiopia

Ethiopia has the largest area of bamboo in Africa by constituting 67% of the total bamboo forest area of the continent and about 7% of the world total bamboo resource. The country has nearly 1 million hectares of bamboo reserves, yet the production and consumption of bamboo and bamboo products is very limited, and value addition is minimal due to poor processing technology [19].

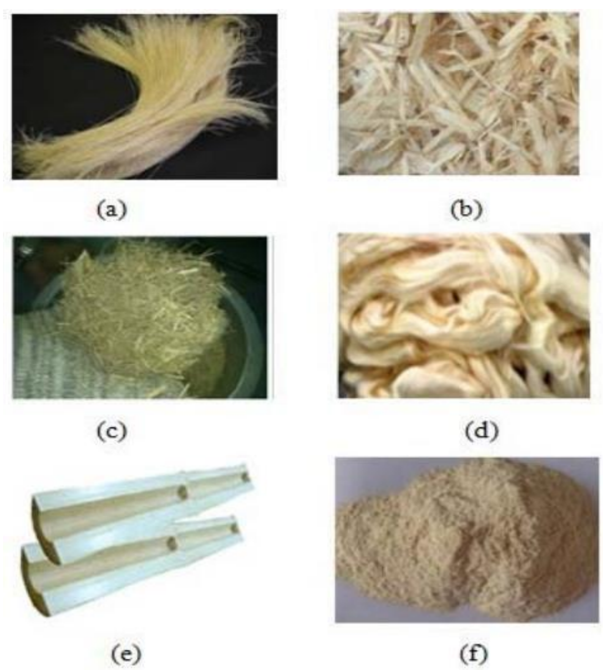
This large resource is dominated by the two indigenous bamboo species; the highland bamboo (Yushania Alpina) and the monotypic genus lowland bamboo (Oxythenantera Abyssinica), [19]. These resources are distributes in the highlands and lowlands of Ethiopia. Assosa, Injibara, Gimbi, Ambo, Gurage, Bale, Masha, Chencha and Hagere-Selam are rich in naturally occurred and planted bamboo forests. The largest source of bamboo plant present in Assosa is lowland type which has solid culm at maturating age [19, 20].

Although bamboo is not an integral part of the economy of Ethiopia, it plays a very important role socially, economically and ecologically in areas where it occurs naturally and where it is planted. It has been used in traditional way in the country side a little bit for the scaffolding, construction of houses, fuel, feed fodder, beehives, hats, mats, baskets, handicrafts, small furniture and other countless products. Recently, a market for bamboo culms and bamboo products has developed [19, 20, 31].

2.4.2 Bamboo fibers

Fiber is a reinforcing material of the composite. Its role is to increase the mechanical properties of the composite. Fiber is stronger and harder as compared to matrix material. Fibers are discontinuous unlike matrix. In the present work, short bamboo strips are used as a fiber material. They were arranged from the local market. Bamboo has better strength along axial (fiber) direction as compared to transverse direction of the fiber. Fibers are densely located around the outer cortex and similarly on the top of the culm. As a result when we examine bamboo timber; from inner to the outer and from the bottom culm to the top, the mechanical strength of the bamboo is increased [21, 22].

Different types of bamboo fibers can be used as reinforcements in composites. Woven bamboo mat, bamboo strips, and long and short bamboo fibers have been used by researchers in different studies. The types of fibers determine the methods of composite fabrication. The types of matrices also influence the choice of fabrication method [21].



(a) long fibers (b) flake (c) short fibers (d) sliver (e) strips and (f) powder.

Figure 2.8: Forms of bamboo being used as composite reinforcement [21].

The chemical constituents of bamboo are primary cellulose, hemi-cellulose and lignin. The bamboo has 60% cellulose and a considerably high percentage of lignin (about 32%) [24].

Table 2.2: Composition of few commonly used natural fibers [24]

Fiber	Cellulose (Wt%)	Hemicellulose (wt%)	Lignin (wt%)	Pectin (wt%)	Moisture (wt%)	Waxes
cotton	85-90	5.7	-	0-1	7.85-8.5	0.6
Bamboo	60.8	0.5	32	-	-	-
Flax	71	18.6-20.6	2.3	2.2	8-12	1.7
Hemp	70-74	17.9-20.4	3.7-5.7	0.9	6.2-12	0.8
Jute	61.1-71.5	13.6-20.4	12-13	0.2	12.5-13.7	0.5
Kenaf	45-47	21.5	8-13	3-5	-	-
Sisal	66-78	10-14	10-14	10	10-22	2
Coir	32-43	0.15-0.25	40-45	3-4	8	
Banana	63-64	19	5	-	10-12	-

The bamboo fiber is often brittle compared with other natural fibers, because the fibers are covered with lignin. Therefore, a devised process should be adopted to extract the bamboo fibers for reinforcement of composite materials [20].

The tensile properties are among the most widely tested properties of natural best fiber reinforced composites. Knowledge of the fiber strength can be an important factor when selecting fibers for particular application. A tensile test reflects the average dimensional property of the fibers. Tensile test is carried out in order to determine the amount of force needed to pull a material or specimen apart and to what extent it will stretch before rupture. The failure to exhibits identical tensile properties can be attributed to the condition under which fibers are left in the environment for retting (dew or water retting), damage caused by processing fibers be hand or mechanized means, types of fibers (long or short fibers), adhesion between fibers in the bundles and fiber orientation [17].

The fiber length and the manufacturing method have a great influence on the tensile properties of the fibers. As mentioned earlier, a longer fiber has a lower tensile properties as compared to a shorter fiber[31, 17]. For example, the tensile stress or strain of flax fiber is not consistent even though the fibers obtained from same region and grown under identical condition. The deformation of the fibers differed between the primary and secondary cell walls [17].

Generally, the tensile strength of bamboo fibers themselves has a stochastic nature, with considerable variability in strength. Stochastic nature is a randomly determined properties of material which can be analyzed statistically but may not be predicted precisely. Having stochastic nature in bamboo fibers will significantly influence the mechanical properties of the composites as the strength of the reinforcements varies [31].

Applications of bamboo fiber and its composites are roof construction, car dashboard & doors, rope, making sheet, paint brush, upholstered furniture, geo-textile, bamboo cycle, computer hardware, bamboo decorative elements, etc [22].

The bamboo fiber has a comparable property with that of glass fiber. More over the mechanical properties of bamboo fiber are comparable to the mechanical properties of the best among natural fibers [20].

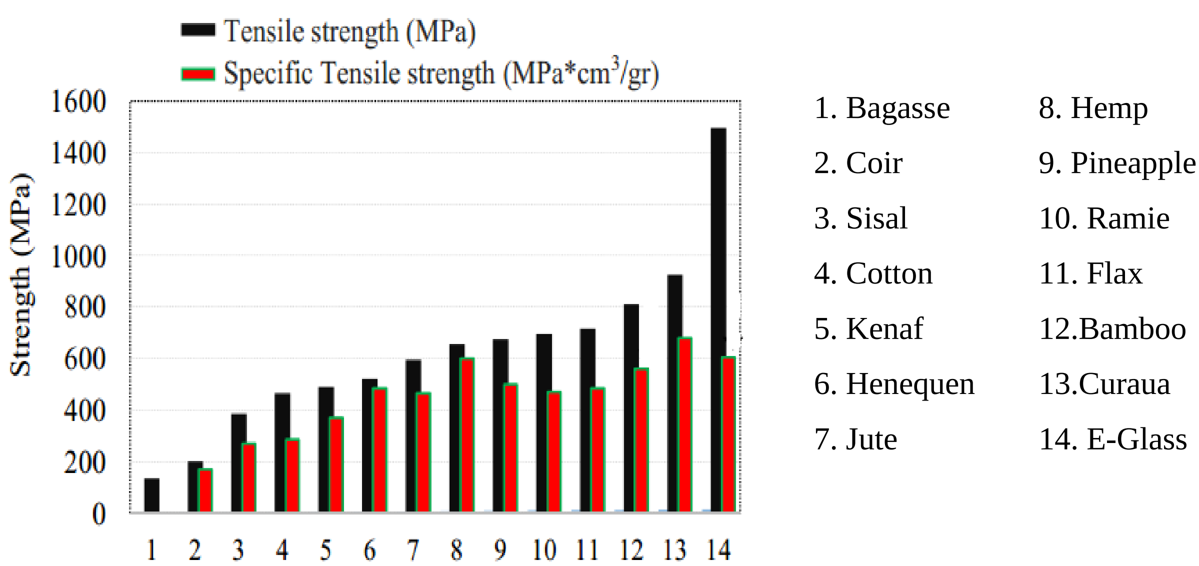


Figure 2.9: Comparison of Natural fibers strength and specific strength [20].

Here in this paper, we are interesting on the polymer matrix composite materials only. They are composed of long chain-like molecules consisting of many simple repeating units. The most commonly adopted polymer composites in more industries are thermosetting and thermoplastic polymer matrix composites. These fiber-reinforced polymer composites can be found in products that people interact with every day, including cars and sporting goods.

Thermoset polymers are polymers that are cured into a solid form and cannot be returned to their original uncured form. Composites made with thermoset matrices are strong and have very good fatigue strength. They are extremely brittle and have low impact-toughness making. They are commonly used for high-heat applications because the thermoset matrix doesn’t melt like thermoplastics. Thermoses composites are generally cheaper and easier to produce because the liquid resin is very easy to work with. Thermoset composites are difficult to recycle because the thermoset cannot be remolded or reshaped; only the reinforcing fiber used can be reclaimed [16].

The advantages of using a thermoset matrix system include the availability of lamination techniques, the possibility of room curing or low curing temperature with relatively low cost, superior mechanical properties in comparison with thermoplastic matrices and higher temperature stability in comparison with thermoplastic matrices. However, the volatile organic compound emissions, difficult recycling or reclaiming procedures, short pot and shelf life may become challenging parameters in some cases. Moreover, it is more difficult to achieve a good surface finish compared to the thermoplastics, depending on techniques used.

Thermoplastic polymers are polymers that can be molded, melted, and remolded without altering its physical properties. Thermoplastic matrix composites are tougher and less brittle than thermosets, with very good impact resistance and damage tolerance.

Thermoplastic composites are less dense than thermosets making them a viable alternative for weight critical applications. The thermoplastic composites manufacturing process is more energy intensive due to the high temperatures and pressures needed to melt the plastic and impregnate fibers with the matrix. The energy required makes thermoplastic composites more costly than thermosets. These two similar materials have such different properties that both will continue to be used in different applications for very different reasons and the products of the future will likely be a combination of both [16].

Thermosetting Polymer Matrix

Among different types of matrix materials, polymer matrices are the most commonly used because of cost efficiency, ease of fabricating complex parts with less tooling cost and they also have excellent room temperature properties when compared with others.

Polymer matrices can be either thermoplastic or thermoset according to the effect of heat on their properties. The thermoset polymer is frequently used as the matrix material due to some advantages it has over the thermoplastic one. The thermoset polymer matrix materials have overall, better economics and high temperature properties. Good mechanical, wetting and adhesion properties and easy to dispose are also the advantages of thermoset polymers.

The most commonly used thermoset resin materials are polyester, vinyl ester, polyester and phenolic. Each resin has its own benefits and drawbacks to use as matrix materials [13].

2.5 Review of previous research arts

2.5.1 Automotive door panel materials and analysis

Alen John et al. [1] give a review on the composite materials used for automotive bumper in passenger vehicles. Determining the right material during the selection process is very important. The material selected should meet the expectation of the engineer. The material should be mechanically feasible and should have low cost. Other than the manufacturing of bumpers, the composite materials have a wide range of other potential automotive applications such as body panels, suspension, steering, brakes and other parts of the automobile. Apart from body panels, the current, limited automotive application of composites include bumper systems, leaf springs, drive shafts, fuel tanks, instrument panels, cross wheel beam, intake manifold.[1]

O.M. Terciu, et.al. [2] Presented the finite element analysis of an automotive door trim panel made of lignocelluloses composites in order to determine the stresses and displacements in case of a door slam simulation. The research was investigated a new lignocelluloses composites made of polymers reinforced with woven fabrics of natural fibers and wood particles. The FEM results emphasized that the new material improves component stiffness compare with classical materials used.

Comparing the results obtained by finite element modeling can be seen that for an acceleration of the impact of 350 m/s^2, displacements of the lignocelluloses composite molded panel are lower by 43% than the plastic molded panel (polypropylene) and its weight is decreasing by 0.3kg.

Even if the result shows that the newly analyzed material has better performance as compared with the classical one, still a large deformation value is recorded. This can be reduced by assessing the more stiff materials.

Mr. Sandeep Bundele et.al[3]focused on Automotive Door Design & Structural Optimization of Front Door for Commercial Vehicle with ULSAB Concept for Cost and Weight Reduction. The paper described the drawbacks of existing automotive door structure and suggests design changes to overcome the present drawbacks.

The new front door assembly components with tailor welded blank technology to reduce weight and cost was designed. Tailor-welded blanks allow combining different strengths of steel in one part without adding complications at the joints. Weight of a door assembly is reducing by 0.4 kg, by reducing weight of a door inner panel by using less thickness high strength material; reduce cost by replacing molded trim with hard pad.

It was successfully solved water leakage problem by modeling front door inner panel correctly. However, the weight of the door panel can be further reduced by selecting lighter materials than steel and designing accordingly.

Tan Wei et.al. [4]dealt with design of the vehicle door structure based on Finite Element Method. The stiffness, strength, modal characteristic and anti-extrusion of a newly developed passenger vehicle door assembly are calculated and evaluated by finite element analysis commercial software. The issue in focus was to predict the performance of the door assembly by powerful finite element analysis software, and optimize the structure to meet the design targets. This method can be used to forecast the performance of vehicle door efficiently when it is designed.

The developed methodology in the design of vehicle door is mainly focused on the outer door panel and the side impact beam only; That shows this research neglectedthe significance of the internal door panels.

Tawanda Mushiri et.al.[5]focused on design of a vehicle door structure based on Finite Element Method. In this paper, the finite element method was used in the development processes of the door assembly. A popular 3-D nonlinear dynamic explicit finite element code with advanced contact algorithms and material models was used to simulate several types of armors subjected to the impact of projectiles moving at various velocities. This paper also has the same gap as the above literature [4].

Said Darwish et.al. [6]Done the Numerical study of automotive doors. Predetermined values from previous works conducted on a similar existing vehicle were used as targets to be achieved by Finite Element Analysis (FEA) of car doors. In this research modal analysis of rear and front doors was in target. For these models both the global stiffness and local stiffness analysis and the vertical displacement analysis were performed.

The research work gave less emphasis for the internal door panel which can play a great role on the weight reduction concept.

M. Raghuveer et.al.[7] researched on Design and impact analysis of a car door. The aim of this work was to analyze the car door with existing material and replacing with different composite materials like Carbon Polyester, S-glass polyester, and E-Glass polyester. Impact analysis was conducted on door for different speeds by varying the materials. This work was going to reduce weight of the door by using composite materials replacing with steel and reduce the damage percentage of the car and passenger protection. The Car door was modeled using parametric modeling software Pro/Engineer.

The strength of the door is increased by change of material from steel to E-glass polyester and S-glass polyester composites. However the glass fiber is denser than natural fibers, so that the weight of the door panel can be further reduced when we use bamboo fiber composites. Since the bamboo fiber has almost equivalent strength with that of glass fiber [20], we can improve the vehicle by reducing its dead weight.

Enrico Mangino et.al. [8] Researched on The future use of structural composite materials in the automotive industry. This paper reported the findings of a recent European initiative that examined the future use of composite materials in the automotive sector. The principal technical challenges that must be overcome in different key areas relating to composite usage are reviewed.

As a general conclusion, design procedures of vehicles body that ensures reliability and road worthiness is well established today. However, as a result of advancements in the areas of material, production methods, computational & design tools, optimization technique, etc., further improvement on vehicle structural design is still an active topic of research. When we see all of the revised literatures, they were focused mostly on experimental researches. Moreover, they were targeted on conventional materials. Thus, conducting the analysis of composite materials for automotive body application may be a good researchable idea, especially by using natural fiber (bamboo fibers) composites.

2.5.2 Mechanical characterization of bamboo fiber reinforced composites

As a fiber, the overall mechanical properties of bamboo are comparable to or even better than those ofwood. Moreover, the specific gravity of bamboo is relatively high when compared to the hardwoods or heavy tropical timber species which are normally used in composites panels manufacturing [10].Thus, it should be used for the high density composite products such as High Density Fiberboard. These advantages make it highly competitive nature fiber reinforcement in polymer composites.

Chandrasekhar et al. [10] conducted tensile, flexural and impact tests to investigate the effect fiber orientations in bamboo/polyester laminates. The orientations were tested at 30°, 45°, 60°, and 90°. The laminated bamboo/polyester was produced by hand lay-up technique. The investigation was concluded that the maximum flexural and impact strengths were achieved at 60°of bamboo fiber orientation and the tensile strength was maximum in 30° of bamboo fiber orientation.

Roslan et al. [11] The tested of fiber orientations of laminated bamboo/polyester composites were at 0°, 45° and 90°. The maximum tensile strength was achieved when the bamboo fiber at 0°, a condition where the fiber is parallel with the load applied.

Zhang et al. [12] chemically treated bamboo fiber with 4 wt% sodium hydroxide (NaOH) for 1 hour. Based on results from tensile test conducted, the present concentration has significant effect on the fiber tensile strength. Moreover, it was found that the treatment increases the effective surface area for better bonding with matrix by removal of bonding materials such as hemicellulose and lignin.

The modifications of bamboo fiber before composite fabrication can be performed by alkali treatment using sodium hydroxide (NaOH) or combination of NaOH and sodium sulphite (Na2SO3).The alkali treatment which also known as mercerization, has been widely used in improving the adhesion of various natural fibers in polymer-based composites [46, 47]. It aims to break hydrogen bonds and create more amorphous cellulose at the expense of crystalline cellulose. The alkali treatment provides not only a very effective surface modification but also a low cost natural-fiber treatment. It was reported that 5% of NaOH treatment results better performance in the composites compared to the ones with untreated bamboo fiber [46, 48]. A certain amount of hemicellulose, lignin wax and oils covering the fiber cell surface can be removed by applying this treatment method. It is because the removing of hydroxyl groups from the natural fibers breaks the hydrogen bonds in the lignin and cellulose which subsequently removes some lignin and makes the cellulose more active toward the matrix.

Shinji Ochi [30] studied the tensile properties of bamboo fiber reinforced biodegradable plastics. Steam explosion method was used to extract bamboo fibers. High strength biodegradable composites were made using an emulsion-type biodegradable resin as the matrix and bamboo fiber bundles as the reinforcement. The unidirectional fiber reinforced composites were fabricated by hot pressing and bamboo fiber bundles with a fiber content of 70% showed high tensile strength of 265 MPa.

Vikram S. Yendhe, et.al.[22] investigated the mechanical behavior of short bamboo fiber reinforced polyester based composites. Bamboo fibers with different length and fiber contents were reinforced in polyester resin to fabricate composite materials. The effect of fiber length and content on the mechanical properties such as tensile strength, flexural strength, impact strength, and micro-hardness of short bamboo fiber reinforced polyester based composites were studied.

SandhyaraniBiswas [23] reported the physical and mechanical properties of short bamboo fiber reinforced polyester composites were studied. Composites were fabricated using short bamboo fiber at different fiber loading.

Sreenivasulu S, et.al.[27] studied mechanical properties of short bamboo fiber reinforced polyester composites with alumina filler. Hand lay-up technique was employed to fabricate composites. Tensile strength of the composite material with filler increases with the increase in filler content by keeping 45% of bamboo fiber constant and flexural strength of the composite material

with filler increase with increase in filler content up to 30% by keeping 45% of bamboo fiber constant.. Many researchers have added synthetic fiber with natural fiber reinforced polymer composite and they found positive result of hybridization in terms of increase in mechanical properties of single natural fiber reinforced polymer composite.

G. Meenambika Bai, H. RaghavendraRao [31]. studied the chemical resistance of Bamboo/Glass reinforced polyester hybrid composites to acetic acid, Nitric acid, Hydrochloric acid, Sodium hydroxide, Sodium carbonate, Benzene, Toluene, carbon tetrachloride and water. The flexural properties of these composites were also studied. The effect of alkali treatment of bamboo fibers on these properties was studied. It was observed that the flexural properties of the hybrid composites increase with glass fiber content. These properties found to be higher when alkali treated bamboo fibers were used in hybrid composites. The hybrid fiber composites showed better resistance to the chemicals mentioned above.

Hemalata jena:[32] describes the hybrid composites using bamboo-epoxy and cenosphere, as a filler material for preparation of the composite. The bamboo fiber is treated with alkali to improve its surface properties. The conventional hand layup technique is used to prepare different composites specimens. 20 numbers of different composites specimens are prepared with varying number of laminate and filler content. Increased in lamina from 3 to 7, the impact strength is increased and increasing the lamina to 9, the strength is decreased. 7 layer composites with 1.5 wt% of cenosphere have maximum impact strength of 18.132KJ/m^2.

Mr. Vikram. S Yendhe, et.al. [33]. In their study, Short bamboo fiber reinforced polyester based polymer composite was fabricated and its mechanical behaviour was studied. It has been explored that the mechanical properties of the composites such as tensile strength, flexural strength, impact strength and hardness are highly influenced by the size of the fibers used. Excess of fibers in composite materials deteriorate the mechanical properties of the composite because of lack of proper bonding between the matrix and fiber around their interface. This causes the disruption in transfer of load to the bonding fibers.

RaghavendraYadavEagala et.al. [34]. Experiments were carried out to study the Abrasive wear behavior of different composites of bamboo and glass fiber reinforced hybrid composite with silica sand abrasive paper. The composite with 20% reinforced gives the best wear resistance when compared to the density is more for the composite prepared with the 10%. The hardness is more for the composites prepared with the 20% reinforced composites. The wear increases with increasing in load and the maximum wear occurs at 15 N.

H. RaghavendraRao, et al [35]. In this study, The Flexural properties and Scanning Electron Microscope analysis of Bamboo/glass fibers Reinforced Polyester Hybrid composites were studied. The effect of alkali treatment of the bamboo fibers on these properties was also studied. In this case also the hybrid composites are found to have good Flexural properties. In the case of maximum strength, the values vary between 60 to 213 MPa. The Flexural strength of these composites are found to be enhanced when alkali treated bamboo fibers were used in the hybrid composites. The hybrid composites with alkali treated bamboo fibers were found to possess higher flexural properties.

Honey banga [27] describes the effect of bamboo fiber at different weight percentage (19, 29,) reinforced to modify polyester resin. Tests are conducted on universal testing machine, Rockwell hardness testing machine and impact testing machine. Composites fabrication was done by compression molding machine (hand layup process). Result shows that 30wt% of bamboo fiber mixed polyester is giving optimum mechanical properties such as tensile, flexural impact properties and increased water absorption of the materials.

Agusedypramono [28] dealt with the bamboo fibers as reinforcement in phenolic resin composites. Composite fabrication was done by hand layup technique. Bamboo fiber diameter 0.5mm, length 280mm, weight of 50:75:100 grams, arranged in a single direction (uni-directional) and double direction (bi-directional). The result of tensile strength test and punch shear test showed that increase in weight of the bamboo fibers may increase the strength of the composite. Composites with bi-directional fibers has a tensile strength lower than uni-directional. Composites with bi-directional fiber have punch shear strength higher than the uni-directional.

Navdeep Sharma [29]fabricated seven different fiber reinforcement polymer composites by hand layup method using short coconut, short bamboo and short glass fiber binding with urea formaldehyde. The different mechanical properties like density, tensile strength, hardness, flexural strength and percentage elongation of specimens were calculated and compare with pure urea formaldehyde resin. The result of bamboo, coconut, glass fibers in urea formaldehyde, there is decreases in the hardness of 20wt% and 10wt% has compared with 0wt% of fibers. Tensile strength of composites is increases with 20wt% of glass fiber. Flexural strength is increases the 10wt% of bamboo fiber. The percentage elongation was increases in 20wt% of coconut.

S. A. H. Roslan et.al. [20] conducted a review on the natural fiber composites based on bamboo fibers. The properties of bamboo reinforced composites from numerous characterization studies of bamboo that are available in the literatures. The review is based on characterization studies on several types of bamboo reinforced composites such as laminated bamboo fiber reinforced composite, randomly oriented bamboo reinforced composite, hybrid fiber reinforced composite, bamboo fiber reinforced bio-composite and bamboo fiber sandwiched structure composite. It can be said that the laminated bamboo composite in general gives higher mechanical properties compare to other structural forms of bamboo composite. Even though bamboo bio-composite in general provides low mechanical properties, the properly design unidirectional bamboo bio-composite can also have high mechanical properties that are as good as the laminated bamboo reinforced composite.

S. Sreenivasul u et al[21] performed the research on Mechanical properties evaluation of bamboo fiber reinforced composite materials. The research has attempted to explore the potential utilization of short bamboo fiber reinforced polyester composites with different weighting compositions, Refer Appendix k, and the information which was used as a validation for experiment conducted in this thesis. It has been evaluated the Mechanical properties such as Tensile strength, and Flexural strength of short bamboo fiber reinforced polyester composites material.

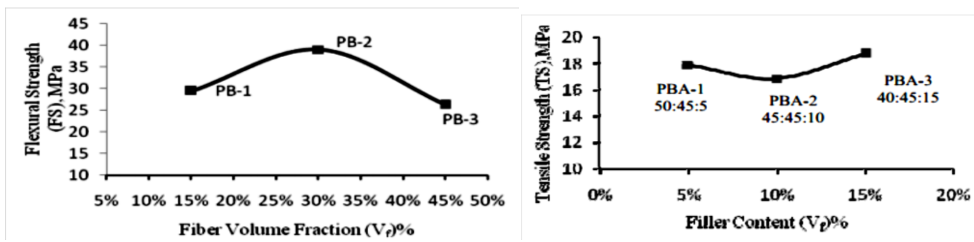
Table 2.3: Mechanical properties of bamboo fiber reinforced polyester composites [21].

Samples	Tensile Strength (MPa)	Flexural Strength (MPa)
PB-1	7.241	29.381
PB-2	8.587	38.989
PB-3	15.601	26.226
PBA-1	17.883	38.109
PBA-2	16.861	45.848
PBA-3	18.767	28.448

The results of this research has been shown that, the mechanical properties of short bamboo fiber reinforced polyester composite material are greatly influenced by the fiber volume fraction and the filler content.

Syed Altaf Hussain et al[22] conducted a research titled as Mechanical properties of short bamboo fiber reinforced polyester composites filled with alumina particulate. It was about the evaluation of mechanical properties namely, Tensile strength and Flexural strength, of short bamboo fiber reinforced polyester composites filled with alumina particulates. Specimens were prepared by hand lay-up technique and are cut as per ASTM standards to perform the test. The experimental result reveals that the mechanical properties of the composite material were highly influenced by the fiber volume fraction (fiber loading). Addition of alumina (Al_2O_3) particulate at various proportions as filler material the mechanical properties i.e., Tensile strength and flexural strength are distinctly improved.

The test results are summarized according to the following graphical expressions.



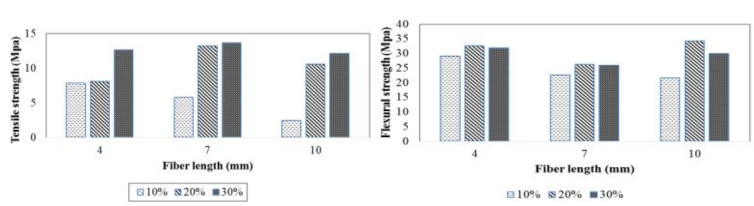
a/. Flexural strength, b/. Tensile strength.

Fig. 2.10: Variation of mechanical properties with respect to the filler content (fiber volume fraction) [22].

Subhash Kumar Gupta, et al[23] A study on mechanical behavior of bamboo fiber based polymer composites. It has been investigate the mechanical behavior of short bamboo fiber reinforced polyester based composites. Bamboo fibers with different length and contents are reinforced in polyester resin to fabricate composite materials.

The effect of fiber length and content on the mechanical behavior of the composites was studied under this research work.

The study tried to verify the mechanical properties of bamboo reinforced polyester based composites such as tensile strength, flexural strength, with their varying composition are explained below.



a. tensile strength, b. flexural strength

Figure 2.10: Effect of fiber parameters on the mechanical property of composite [23].

D.Dash, S.Samanta et al[24]; Conducted the mechanical characterization of Natural Fiber Reinforced Composites (NFRC) consisting of polyester resin reinforced with jute fiber and bamboo fiber. Hand lay -up technique was used for fabrication of the composite specimens. The effect of fiber orientation (0 /90, 15 /-75, 30 /-60, and 45 /-45) was analyzed and it shows that the fiber orientation of 0 /90 provides higher strength and stiffness than other fiber orientations used in this work.

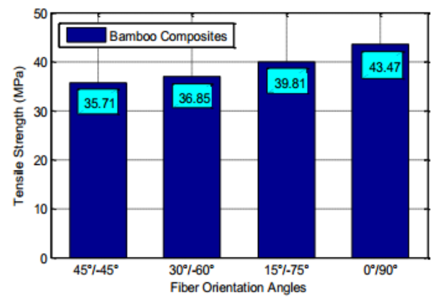


Figure 2.11: Effect of Fiber Orientation on Tensile Strength of Bamboo Composites [24].

The natural fiber reinforced composite can be used in places where light load application is important and the economics of natural fiber composite materials is more beneficial as compared to E-glass fiber composites.

Dheeraj Kumar (Asstt. Prof.)[25] Characterization of tensile properties of treated bamboo natural fiber polymer composite. The paper tried to show the practical observation which includes characterization of mechanical properties of potential bamboo fiber. The fabrication of the samples was made by hand lay-up technique.

Table 2.4: Sample Composition

Designation	Composition	No. of Samples
B	Pure Polyester	5+5+5 = 15
B1	Polyester (95%) + Bamboo Fiber (5%)	5+5+5 = 15
B2	Polyester (95%) + Bamboo Fiber (10%)	5+5+5 = 15
B3	Polyester (95%) + Bamboo Fiber (20%)	5+5+5 = 15
B4	Polyester (95%) + Bamboo Fiber (25%)	5+5+5 = 15
B5	Polyester (95%) + Bamboo Fiber (30%)	5+5+5 = 15

The Result shows the variation in tensile strength in respect with the variation in fiber content (%). The tensile strength of bamboo-polyester composite increases to the certain level of fiber loading and then starts decreasing on further fiber loading.

Table 2.5: Tensile strength of bamboo fiber polymer composite with random orientation

Designation	Fiber Content (%)	Orientation (Degree)	Tensile Strength (MPa)
B	0	-	18.16
B1	5	Random	26.22
B2	10	Random	37.98
B3	20	Random	45.28
B4	25	Random	53.61
B5	30	Random	46.91

The result shows that the tensile strength of bamboo-polyester composite increases to the certain level of fiber loading and then starts decreasing on further fiber loading. The maximum value of tensile strength is obtained at 25wt% of fiber loading.

Vivek Kumar et al[26] Researched on High Performance Moldable Bamboo Fiber-Polyester Composites. For development of the composites, woven bamboo mats were used where the bamboo was stripped into narrow strips, about 4.25mm wide and about 0.5 mm in thickness.

The composites contained between 30-40 wt.% fibers, although up to 60 wt. % fiber can be used. Fillers such as carbon black and fly ash can also be added to these composites. The composites exhibit tensile strengths of 140MPa, flexural strengths of 160 MPa and notched Charpy Impact strengths of 60kJ/m2. These composites were molded into auto body parts (dashboard, doors, and panels) and are under test with an auto-rickshaw manufacturer

Fekadu Tarekegne et al[18] Researched on the study of Ethiopia high land bamboo composite for structural materials. The main objective of the study was to introduce the industrial application of bamboo to bamboo sectors of the country by investigate the performance of bamboo fiber composite. The experimental analysis was carried out by using a short bamboo fiber reinforced polyester composite (with bamboo fiber content of 25 wt. %) to evaluate its mechanical properties. The fiber was extracted from a two years old highland bamboo (bamboo from Injibara). These experimental results were summarized by the following table, (Table 2.9):

Table 2.6: Mechanical properties of bamboo fiber reinforced polyester composites

Mechanical Properties	Values	Test Standards
Tensile Strength	187.73 MPa	ASTM D638
Flexural Strength	190.32 MPa	ASTM D790
Compression Strength	114.13 MPa	ASTM D695
Shear Strength	18.18 MPa	ASTM D638
Water Absorption	2-3%	24 hour submersion
Youngs Modulus	3852	-
Shear Modulus	1580	-

From these results the researchers concluded that the analyzed BFREC material has attractive mechanical properties which can replace the current structural materials.

The research was commissioned by Fortune Enterprise P.L.C collaborated with GTZ on a public private partnership project (PPP). The PPP has the objective of establishing a sustainable production of high value composite bamboo materials, and promote industrial production.

Review Summary

Generally to summarize this chapter, several experimental investigations were done to characterize the mechanical properties of the bamboo fiber reinforced composite materials. As we have seen from the above reviewed literatures, the bamboo fiber reinforced composites have mechanical properties comparable to currently used engineering plastics and are appropriate for application in automotive body parts.

CHAPTER THREE

3. MATERIALS AND METHODS

This chapter details the materials and methods used for making the composites as well as the chemical treatments and the machines and methods used to characterize the composites.

3.1.Materials

As we have seen from different literatures (previous chapter), bamboo fiber has better mechanical properties as compared with other natural fibers. Bamboo fibres are often called “natural glass fibres” because of their properties [36]. Among the well-known natural fibres, bamboo has a favourable combination of low density and high mechanical properties giving good specific properties (i.e. stiffness and strength). Therefore, using this plant fiber as reinforcement in composite materials for different structural components by replacing the currently used conventional materials will have a competence advantages.

In this analysis the bamboo fiber/polyester composite materials with a considerable composition are used as the materials of door panel for three-wheel compact 205 models Bajaj of an automotive. The materials and equipments used in this thesis which are purchased from local market are as listed below:

Table 3.1: Material Utilized

No	Item	unit	Quantity /Unit
1	Bamboo Fiber (woven two roll 8kg)	Roll	2-Roll
2	Polyester resin	kg	6kg
3	Hardener	Lit.	1/2lit.
4	Wax	kg	1kg
5	Gel coat	kg	1/2kg
6	PVa	kg	1/2kg
7	NaOH	Lit.	0.37 lit.
8	Plastic sheet	meter	2x2
6	Distilled water	Lit.	20 lit
7	Fiber glass (E- glass)	kg	1 kg

Table 3.2: Equipment Used

No	Item	Quantity/unit
1	Molds (Two flat surface plate & Two thick sheet metal)	4
2	Mixing container	2 lit.
3	Normal Brush	4
4	Roller Brush	1
5	Steel Rule	1/2 m
6	Test machines	2
7	Weighting machine	2
8	Grinding Machine	1
9	Welding Machine	1
10	Drilling Machine	1

3.2.Methods

Procedure of Fabrication of Composite

- Primary survey
- Secondary survey
- Design and fabrication; and
- Experimental tests were described in detail in this chapter.

Procedures for fabrication of the composite

- Preparation of the Fiber
- Chemical treatment of the Fiber
- Preparation of mould
- Post curing of the mould
- Removing specimen from mould & cleaning
- Weight the Composition
- Cutting the laminate into standard size specimen for test.

3.2.1. Bamboo Fiber Reinforced Composite Preparation

3.2.1.1.Preparation of Bamboo Strip

A). Modification of Bamboo Strip

The samples were prepared using hand lay-up technique. Hand lay-up technique was adopted to fill up the prepared mold.

The natural bamboo fiber was purchased from local market with the dimension of 3-meter length by 2-meter width size and 0/90° meshed and ready to sell for other purpose.

To prepare the first sample, use one roller and separated the whole meshes into singular pieces. This process helps to change the previous bamboo strips thickness into the proper research sample size.

a).waved roll bamboo b). splitting process c). splinted bamboo d). final prepared bamboo strip

Figure 3.1: Preparation of bamboo strip steps

3.2.1.2.Chemical treatment of bamboo fiber

The bamboo strips were cut into 60cm soaked in 5% NaOH solution at normal room temperature for 6 hours. The treated bamboo strips were perfectly cleaned in water and excess water was dried. For this thesis work, a ratio of 95% water and 5% sodium hydroxide-NaOH were used. The sample solution was used to mix ratio of 7-liter distilled water to 0.037 liter-NaOH. The long striped 60cm bamboo strips submerged into chemical solution for 6-hours.After 6hours of staying time, chemical solution was drained out and the fiber was rewashed by tap water to keep the PH value to almost neutral. Finally the fiber dried in direct sun light for about 6hours. The following reaction takes place as result of alkali treatment:

$$\text{Fiber} - \text{OH} + \text{NaOH} \rightarrow \text{Fiber} - \text{O}^{-} - \text{Na}^{+} + \text{H}_2\text{O} \; [13].$$

NaOH + distill water = mixing NaOH with H_2O → bamboo submerging

Figure 3.2: Bamboo strips chemical treatment process

B). Fiber orientation

According to privies' study, the effect of orientation on mechanical properties, mold is going to prepared in 0^0 and $0/90^0$woven form and its weight measured in digital weight metering machine. 0 and 90^0 can be prepared from the first fiber arrangement shown from the Figure 3.4.

- ❖ The following figure shows that first sample produced by using both orientations on the same layer.

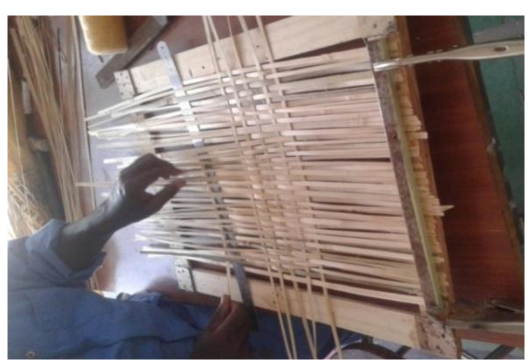


Figure 3.3: preparing both 0 and 0/90 woven on one layer.

- ❖ From the above research data only two different fiber orientations are used as indicated below:

a/ 0°orientationb/ 0/90°orientation

Figure 3.4: orientation of 0 and 0/90° degree bamboo strip

C). Measuring within digital weight measurement device

- ❖ According to the digital measuring device value, woven bamboo fiber was weighted 148.5g.

Figure 3.5: measuring weight of unidirectional &woven bamboo fiber

3.2.1.3.Preparation of mould

Hand Lay –Up Technique

The composite are fabricated using the hand layup technique. First, the inner surfaces of an open mould (the same size as the specimen) are coated with a thin layer of the release agent. The Polyester resin is mixed with 1wt% methyl ethyl ketone peroxide catalyst as hardener. Bamboo fiber then placed on was put in the mould and mixed resin poured on it and brushes over the bamboo fiber to spread the resin and after that put another longitudinal bamboo fiber and provide the load on it. This process was repeatedly done until the desired thickness achieved. Specimens were fabricated with different fiber orientations such as 0^o, 90^o and $0^o/90^o$ for bamboo fiber reinforced composite.

The following steps involved the mold preparation for bamboo fiber reinforced composite.

A) Working Station preparation

An initial preparation of all the materials and tools that are going to be used is a fundamental standard procedure when working with composites. Prepare ALL materials and supplies available and set up before proceeding.

B) Cleaning and applying a release agent

Preparation consists of cleaning the mold and applying a release agent in the surface of it to avoid the resin to stick. If this was an actual mold, do the following:

- Clean the mold with a clean cloth.
- Apply release agent in the surface of the mold.
- Wait certain to set up the release agent.
- Buff with clean cloth.

Mold Release Agents

Mold release is essential for preventing the polyester from sticking to the mold when the composite are apart. Even though, there are several types of mold release used depending on the mold material and desired characteristics of the finished part, the most common type and used for thisthesis work is paste wax (oil), and polyethylene plastic for better surface finish of the composite.

A).PVA (Polyvinyl Alcohol)

To start directly into the process, coat the surface of both sides' plates by PVA softly and uniformly. The purpose of this fluid was to facilitate the release process.

B). Apply Wax

Wax was first used as a release agent in the composites industry in the 1950's. Carnauba wax-based products are the most suitable for use with composite materials and these are widely employed, particularly in contact molding applications.

Silicone modified products can be used but care has to be exercised as silicone can interfere with the release interface making separation difficult. Any silicone-based release agents should be thoroughly tested before use.

Wax release agents are available in several forms but those most commonly used are pastes or liquids. Among the advantages of wax release agents are their ease of use, convenience and economy. Waxes are used mostly in low volume contact molding applications, as the need for regular re-application can be time consuming.

Figure 3.6: Wax -release agent

3.2.2. Polyester resin matrix preparation

Polyester resin preparation; the first step is to mix the resin and the hardener. The proportions are usually given by the supplier and can be found on the containers of the hardener or resin. But most researcher were applied the ratio of resin and hardener 10:1 / 11:1 respectively.

Finally, polyester resin and hardener are weighted for suitable mixing ratio and then manually mixed for 15 minutes to have good homogeneity between polyester resin and hardener.

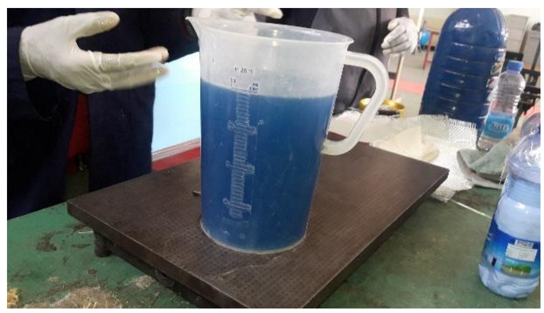


Figure 3.7: Preparation of polyester with hardener.

Reinforcing Fibers

In this experiment a standard E-fiberglass cloth and woven bamboo strip were used.

Steps which were followed during production of samples:

i). Apply the fiberglass (or E-glass fiber)

Glass fibers are a very versatile class of materials. They are used extensively as a reinforcement fiber for polymeric resins such as polyester and unsaturated polyester.

- First cut the fiber glass a little more than mold surface size and put this glass fiber on base surface plate.
- Add mixed resin on the surface area of a glass fiber.
- Use normal and roller brush to distribute the chemical solution uniformly and to remove out air bubbles from a glass fiber plus resin surface.

ii). Applied Woven fabric bamboo material

- Put the woven bamboo fiber (Plain weave)on the fiberglass & add more resin again to a layer.
- Finally, repeat the same procedures which are mentioned above; Use normal and roller brush to distribute the chemical solution uniformly to remove air bubbles from the mold and the laminate surface.

iii). Apply the final top E- glass fiber

- Apply the final top layer of E- glass fiberon the natural bamboo fiber.
- Add more resin on the surface area by normal hand brush.
- Roll within roller brushto use to spread it around all surface, smoothly into the resin chemical on the whole surface area and also to remove out air bubble from the mold surface.

Figure 3.8: Applying resin on E-glass with brush

iv).Post curing of the mould

In order to trap the air bubbles, the laminate was pressed in by the weight press. Sufficient weight was placed on the top of the laminate surface uniformly and kept for duration of 24 hours. For the purposes of this experiment and application of a polyester resin efficiently, the room temperature was at optimum.

v).Removing specimen from mould & cleaning

Best results are obtained by allowing the molding to stabilize for 24 hours at ambient temperature. After curing for 24 hours remove the pressed heavy materialand prepare the mold for weight measurement.

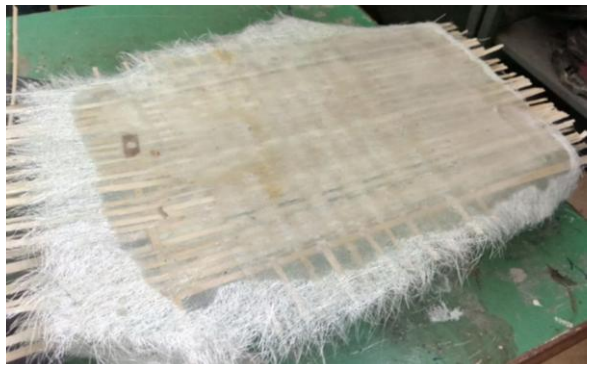


Figure 3.9: Final mold after removed from load press

vi).Measuring the mold weight

- ❖ Weight of the mold was measured using digital weight measuring device.
- ❖ According to the measurement, weight was 1103.5g. (approx. 1.1Kg.)

Figure 3.10: Measuring the mold

vii).Removing out off press mold

Finally cut & remove extra mold part out from surface plate area. The final dimension was 300x400 x3.5mm volume.

Figure 3.11: The final prepared mold for specimen in both sides and its weight

Weight Composition

Like other types of natural fiber composite preparation process, it is possible to determine the weight composition of constituent used materials. After forming the required fiber orientation each component is measured except the resin. Two layers E-glass fiber is used with the bamboo strip fiber in the middle. So to have the resin composition it is possible by subtracting summation of fibers from the composites weight.

- As the measurement shows in figure 3.6 that bamboo fiber woven weights 215.5g and
- A single layer of E-glass woven is 32.75g
- But in composite plat production with a frame of 400mm by 300mm, two layer of glass fiber one in the bottom and the other one in the top is used.
- So the total mass of fibers used for this sample become:
  - 154.0g+2(32.75g) = 219.5g
  - While the matrixes weight can be estimated by subtracting from plate weight which measures 635.0g.

The weight composition (%w) can be determined by using a mathematical approach between ingredients mass and total mass. Therefore;

- ✓ The %w of fiber $= ((\mathrm{W_{fiber}}) \,/\, \mathrm{W_{composite}}) * 100$,
- ✓ Finally%w of fiber $= (219.5\mathrm{g}/635\mathrm{g}) * 100 = 34.57\%$

- ✓ The remaining weight fraction is the matrix one which is the weight fraction of polyester resin,
  - Numerically%w of resin $= (415.48\text{g}/635\text{g}) * 100 = 65.43\%$.
  - As many researchers agreed that to have better mechanical properties of natural fiber composite the weight composition should be around 35/65% by ratio for fiber and matrix respectively.

The density of the material can be determined from this measured weight value and average dimension measurements. So the average dimension reading of a 635g composite material is 400mmx395mmx4.0mm. Therefore,

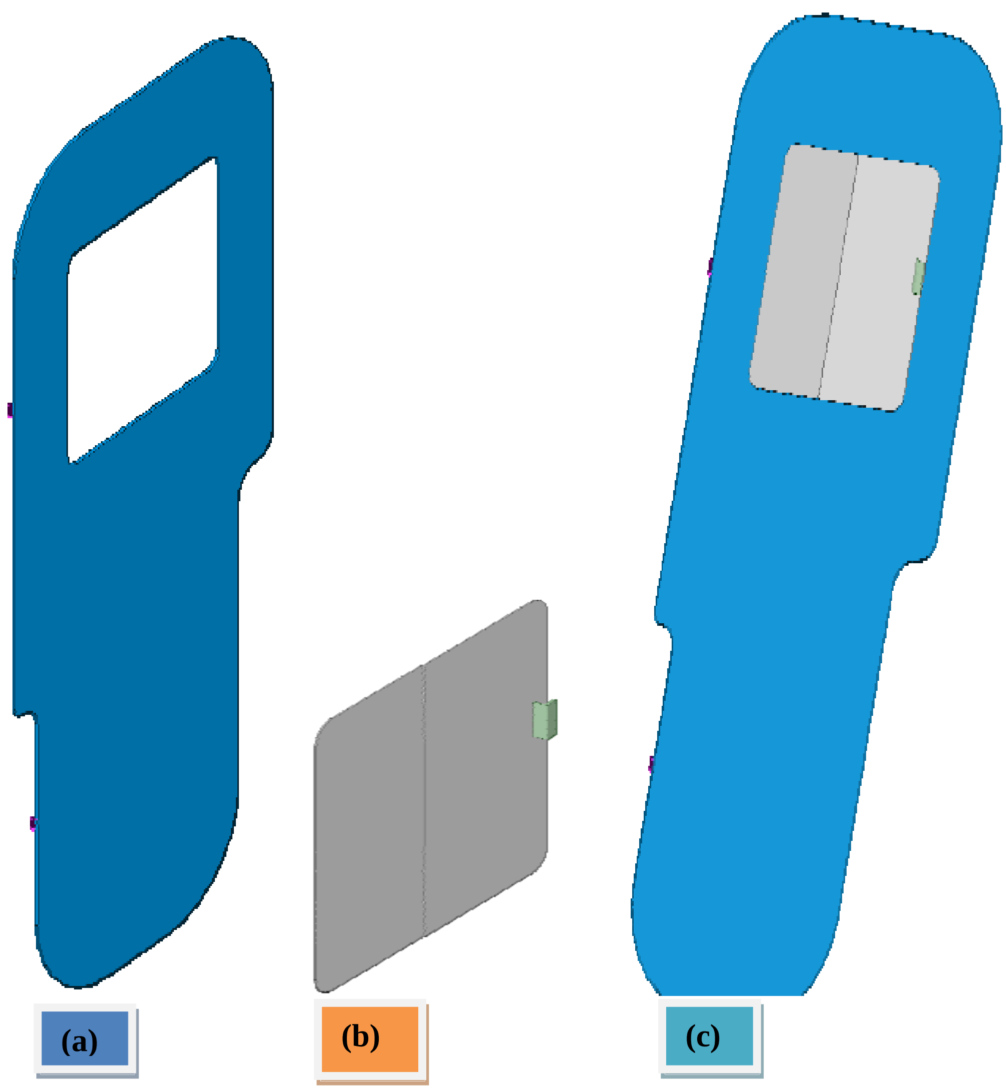
- ❖ The density can be calculated as follows $\rho = (635\text{g}/(40\text{x}39.5\text{x}0.35)\text{cm}^3) = 1.15\ \text{g}/\text{cm}^3$Using formula $\boldsymbol{\rho} = \boldsymbol{mass}/\boldsymbol{volume} = \frac{\boldsymbol{m}}{\boldsymbol{v}}$

Generally the composite preparation was carried out through following steps:

- ➢ The purified and dried bamboo fiber was arranged according to required fiber orientation, in this work three fiber orientationwith better performance (0^0, 90^0 and$0^0/90^0$ woven) is used base on literatures.
- ➢ Cut E-glass fiber woven for the size of metal surface plate.
- ➢ Determine the weight of wovenbamboo fiber and S-glass fiber to be used.
- ➢ Polyester resin is mixed with 1% of catalyst and steered for 15min., which helps to minimize the composites curing time.
- ➢ Apply Pva and wax on the mold surface by using clean cloth respectively.
- ➢ First single E-glass layer is placed on the mold then matrix is applied and it was dispersed well with the help of brushes and roller. After checking as the resin spreads well, prepared bamboo fiber orientation layer over the resin. Again apply the matrix and rub very well to avoid trapped air with natural fiber to prevent the formation of porosity which initiates crack for failure. The third layer was added with similar fashion as previous. Finally load is applied to remove excess resin and attain minimum thickness of the composite material.

3.2.3. Modeling of the door

❖ Modeling of 3-wheel compact model Bajaj door component using CATIA software.



a).model of door panel without window (glass) assembly b). Slide type window

c). Assembly model

Figure 3.12: Component parts of 3-wheel Bajaj rear side door panel

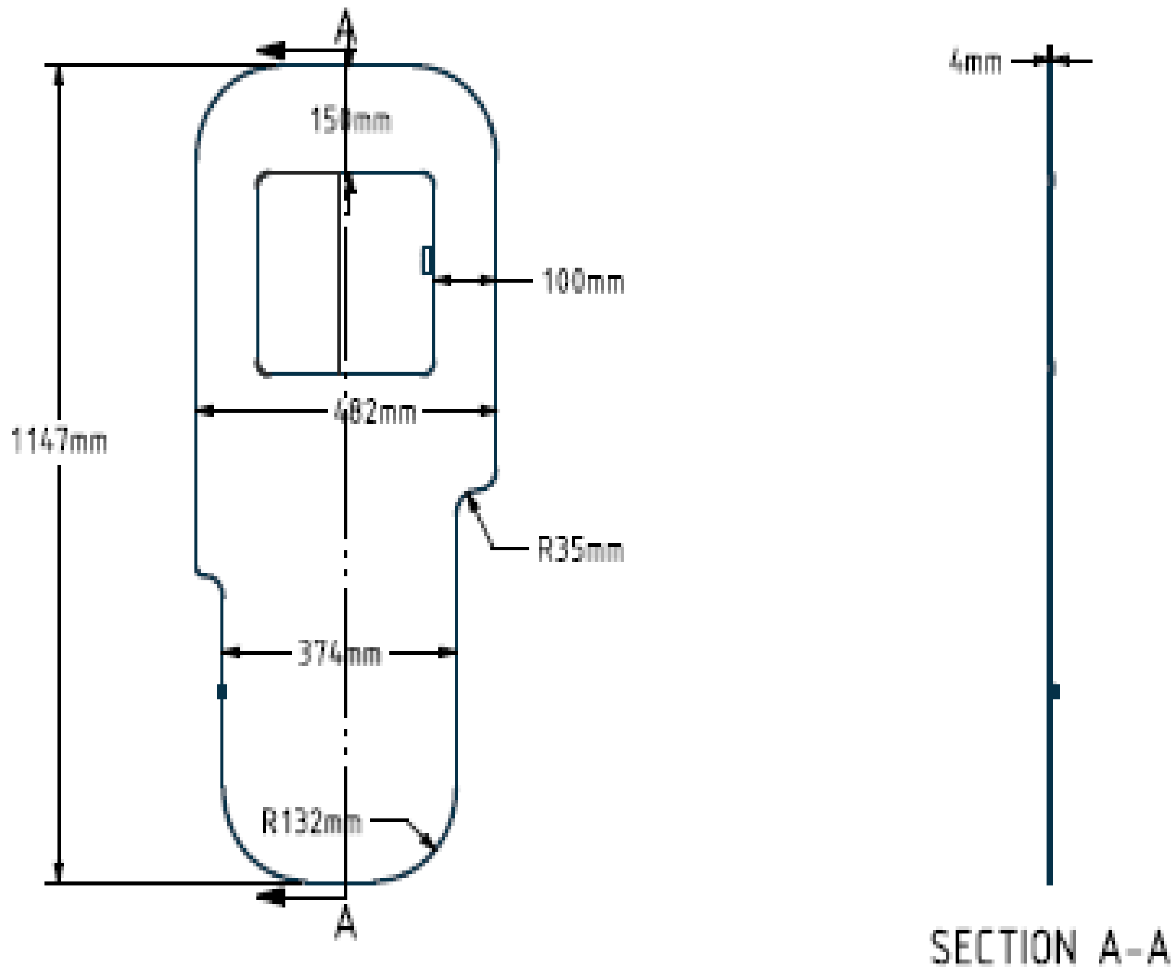


Figure 3.13: Model drawing of three- wheel Bajaj for compact model 205 rear side door

CHAPTE FOUR

4. TEST RESULTSAND FABRICATION

4.1. Testing of sample specimen

For this thesis work the specimen is prepared as per the requirement of company's machine capability and technician's precision ability to cut according to the given dimension.

Figure 4.1: Test specimen preparation using Band Saw in AAiT

As there is no standard machine to prepare the composite materials test specimen, average dimension and other properties are taken out of three trials. Each test is verifiedwith three samples for the case of three fiber orientations 0°, 90^0, $0/90^0$/as describer in section.

4.1.1. Tensile test

The dog bone type of tensile test specimen is prepared in Addis Ababa Institute of Technology, mechanical engineering workshop. Even final specimen dimension measurement has deviation from expected/ordered standards, tried to have an average of three specimens for accuracy.

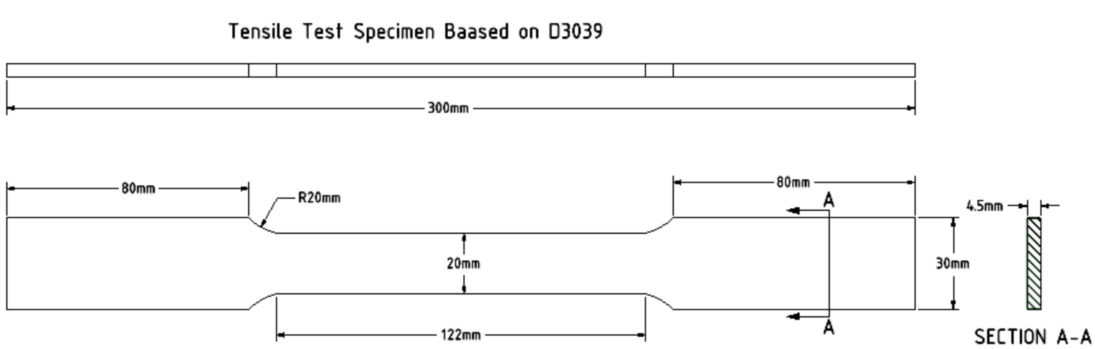


Figure 4.2: Dimension for tensile test According to ECAE test sample

These specimens are prepared depending on the EACE's UTM machine standard dimension. From each fiber orientation composite plate, three test specimensare required to take an average for better accuracy. Specimens are designated as A_{11}, A_{12} ...$A_{33,}$ for 90^0, 0^0 and $0/90^0$respectively for researchers' identification. The graph shows that stress [N/mm^2] to strain [%] properties of different fiber orientation natural fiber to polyester matrix composite.

Figure4.3: Test specimen for tensile strength

Tensile test is executed in Ethiopian Conformity Assessment Enterprise in Addis Ababa, Ethiopia. The UTM is connected with computer display and it able us to pint the test output/stress-strain curve in this case. The machine used for the tests has strength correction factor after having direct computer printout data depending on the load applied to break the specimen.

Figure 4.4: Tensile test machine under the operation process

The graph reading of the first testof 90^0 fiber orientation composite in thefigure A_{11}shows that, the material with bamboo fiber to polyester resin composite have a tensile strength of 64.6Mpa with a strain of 9.5% elongations. In the case of 90^0 fiber orientation the fibers longitudinal direction arrangement is perpendicular to that of applied force vector, the matrix, force transmitting component from one fiber layer to another is expect to fail early due to layer separation. So this arrangement has less strength in tension as compared with 0^0 and $0/90^0$ woven fiber arranged composite.

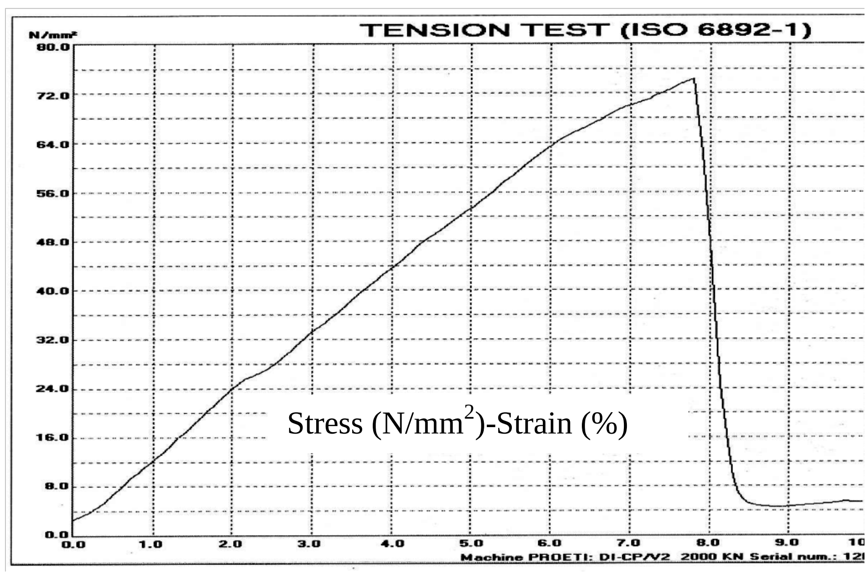


Figure4.5: A11 (first test for 90° orientation)

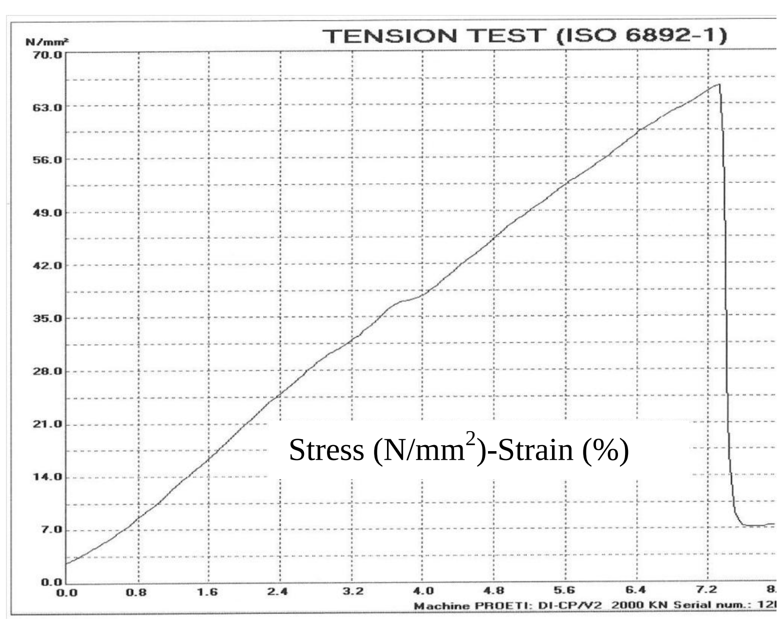


Figure 4.6: A12 (2nd test for 90° orientation)

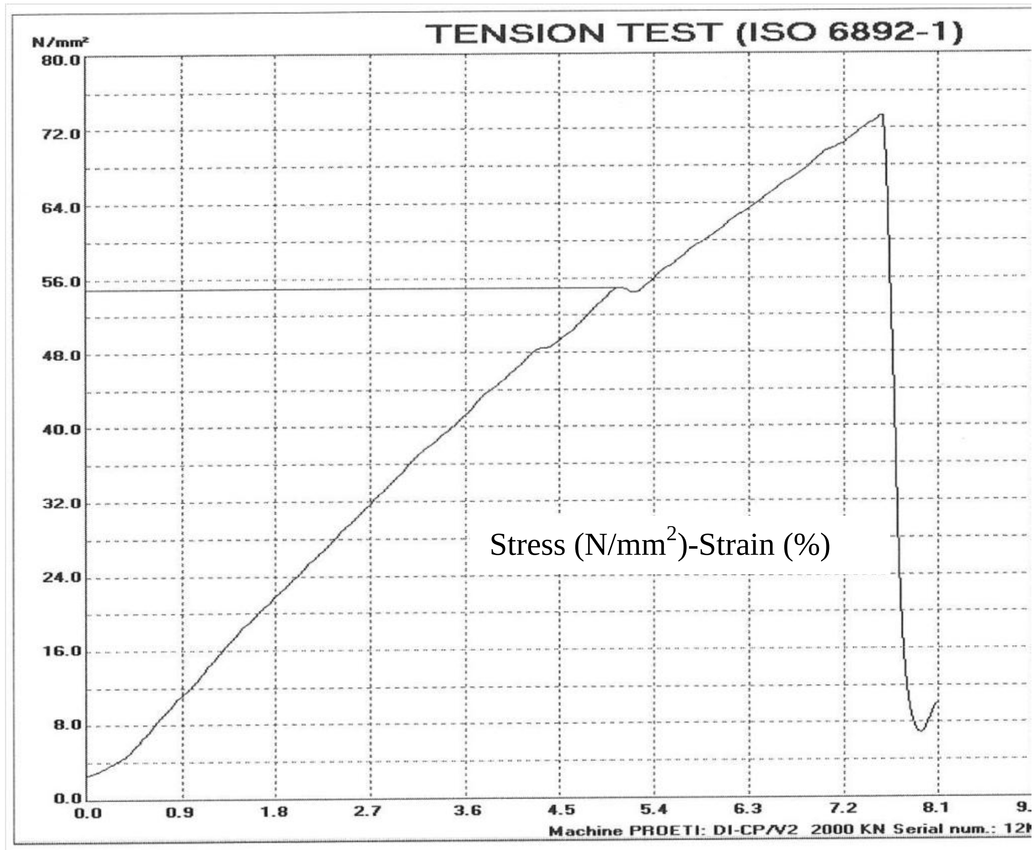


Figure 4.7: A13 (third test for 90° orientation)

From second test of 90^0 fiber orientation composite, the specimen fails after elongation of 7.2% and reaches at a tensile strength of 55.9Mpa without considering machines correction factor. The last test result of the tensile strength of this specimen reads 64.1Mpa with the elongation of 7.3%.

The tensile strength obtained from the above three tests can be considered and the average value is used for design consideration to minimize personal errors. So the average value of tensile strength for 90^0 fiber orientation becomes 61.53Mpa.

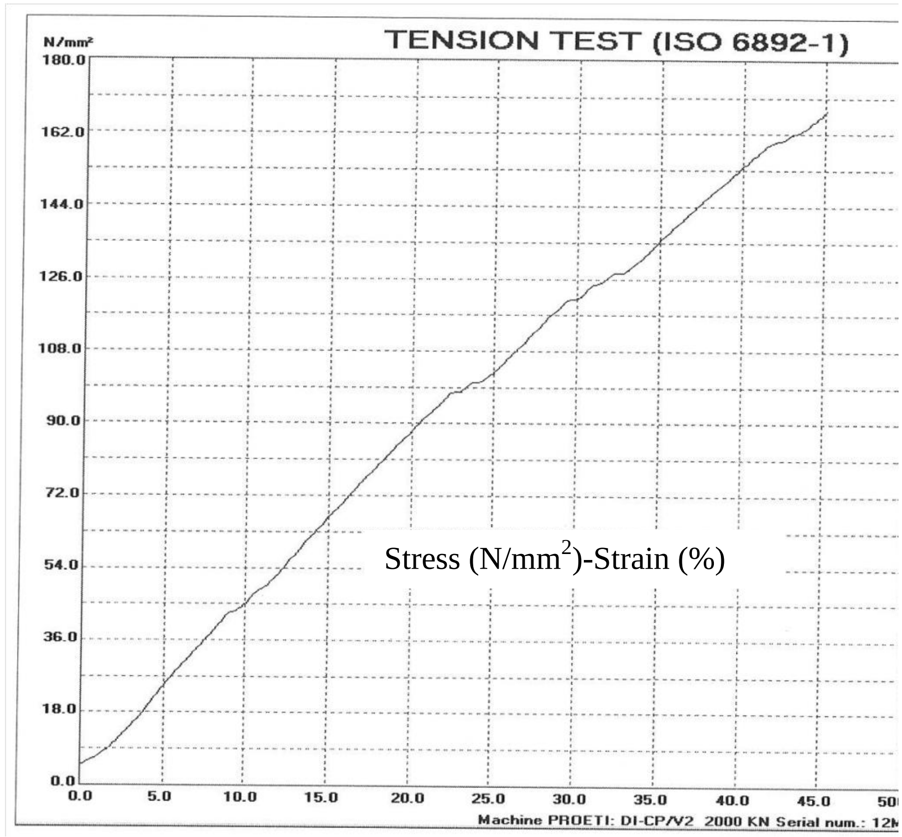


Figure 4.8: A21 (first test for 0° orientation)

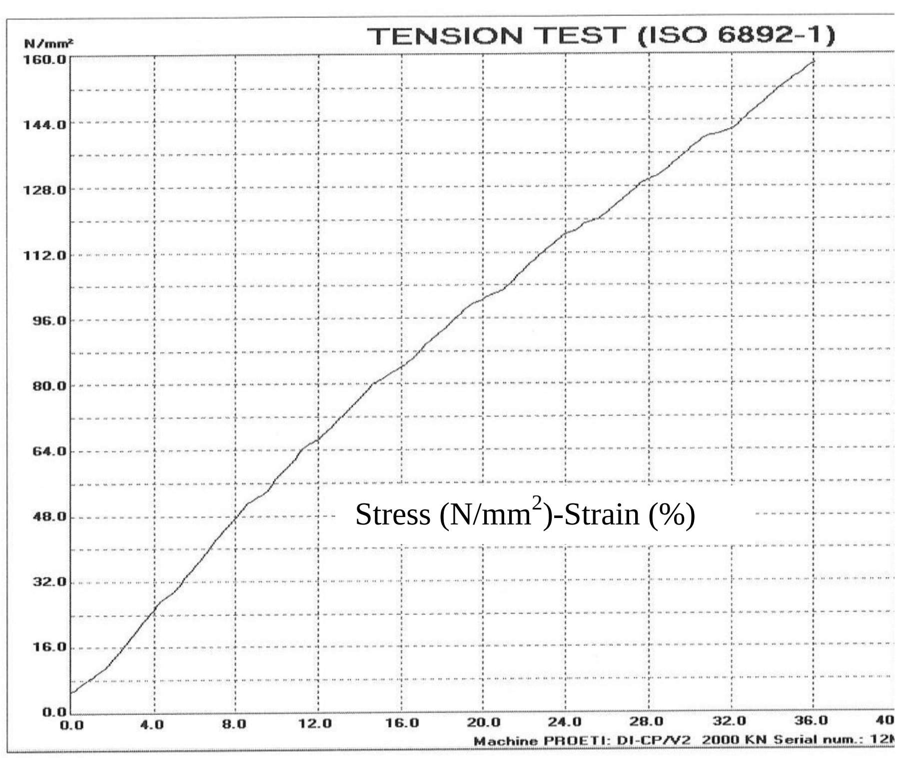


Figure 4.9: A22 (Second test for 0° orientation)

The second composition type under consideration in this work is 0^0 fiber orientation type. This differs from 90^0orientationscomposite; the longitudinal reinforcement fiber orientation is perpendicular to the applied force vector direction of the UTM. In this case each fiber is responsible to carry the load and should be break for in order to fail the specimen. Layer separation will not be takes place in most cases.

The stress-strain relation of prepared test specimen results is presented in the figures A_{21}, A_{22}, and A_{23}. From first test (figure 4.8), materials tensile strength is becomes 155.3Mpa with a corresponding strain of 10.3%.

Similarly for the second test(figure 4.9) of this composite type the tensile strength and the corresponding strain are 145.5Mpa and 9.6% respectively.

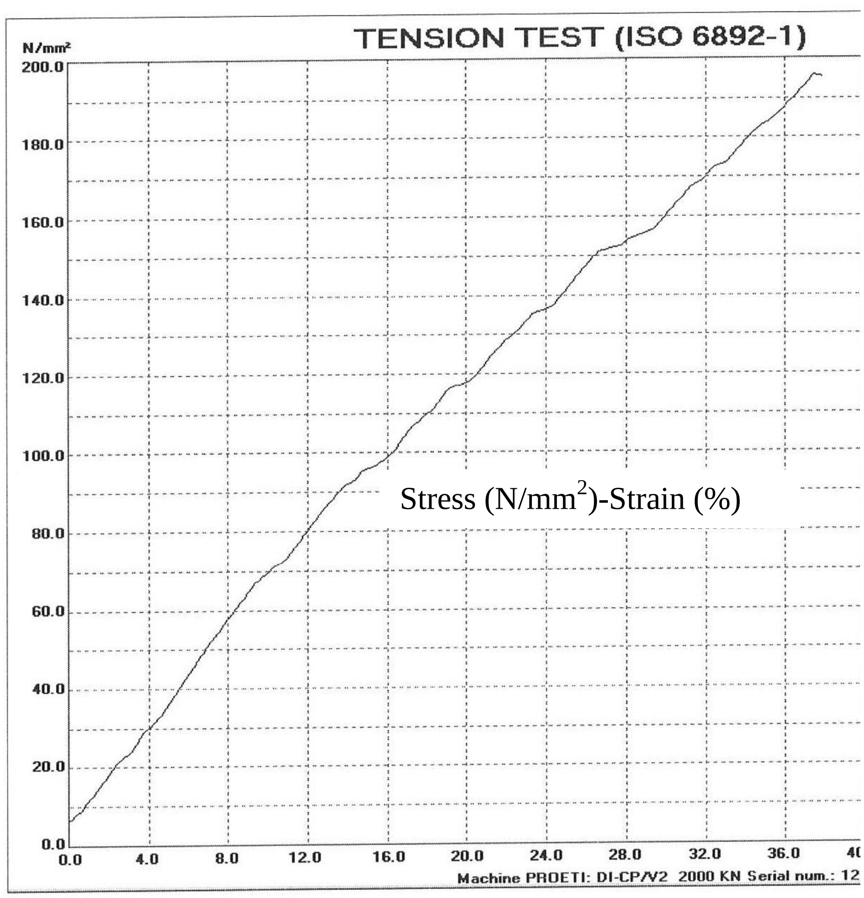


Figure 4.10: A23 (third test for 0° orientation)

The final sample test for the corresponding fiber orientation composite shows that the tensile strength is going to 178.4Mpa and the percentage corresponding elongation is to 10.8%

So for those three sample testes describes above, the average is used to summarize as the tensile strength of 0^0 fiber oriented Ethiopian origin bamboo fiber with polyester resin composite material is 159.73Mpa.

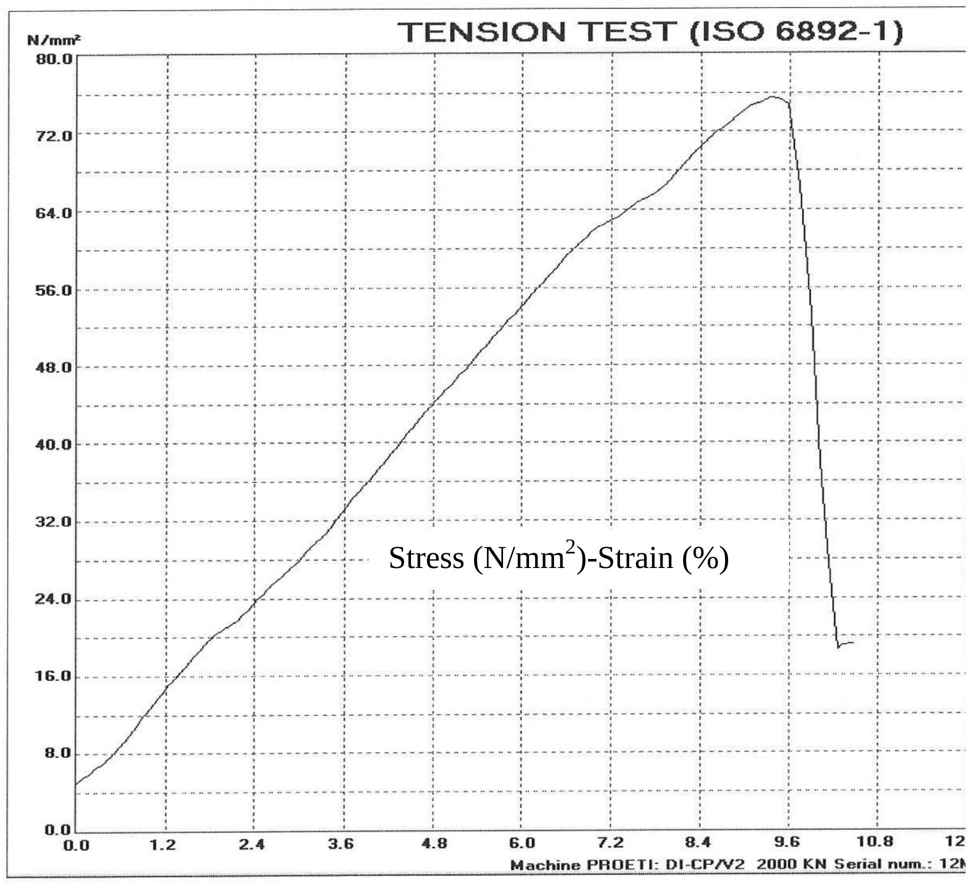


Figure 4.11: A31 (first test for 0/90° orientation)

The last tensile strength analysis is on $0/90^0$ woven bamboo fiber orientation to polyester composite. As like previous, here also tree test samples are conducted and finally the average one is considered as strength property for this newly treated composite material.

First test of the last fiber orientation sample have a tensile strength of 69.5Mpa with a corresponding strain percentage of 8.4% as designated by A_{31} in figure 4.11.

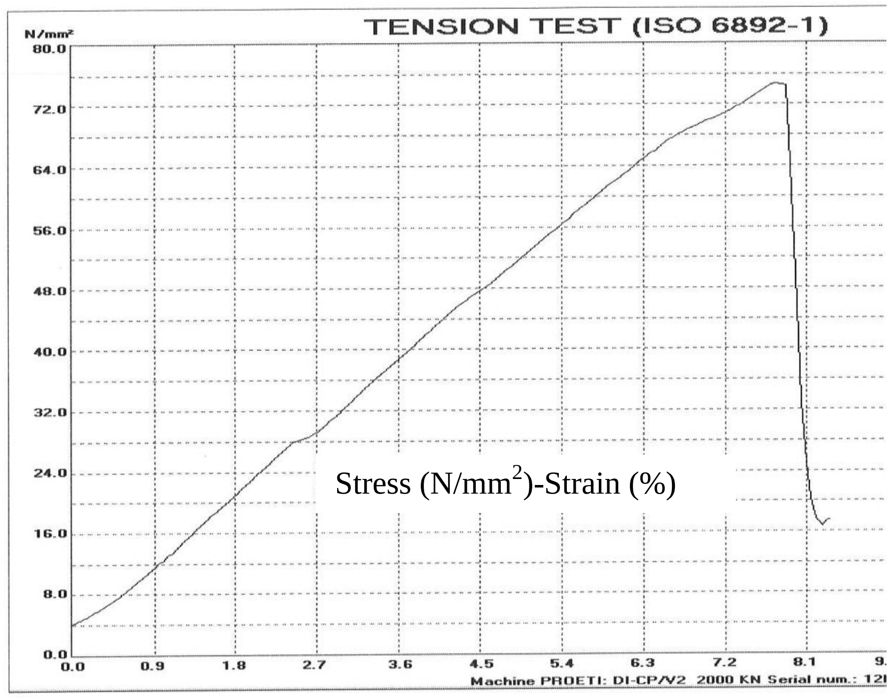


Figure 4.12: A32 (Second test for 0/90° orientation)

Figure 4.12 reading shows that the tensile stress of Bamboo fiber-GP resin composite in a $0/90^0$ woven form is 68.4Mpa while the third sample is 63.7Mpa with a corresponding percentage elongation of 6.7% and 7.8% respectively. Finally the average tensile strength of composite with this specified fiber orientation becomes 67.2Mpa.

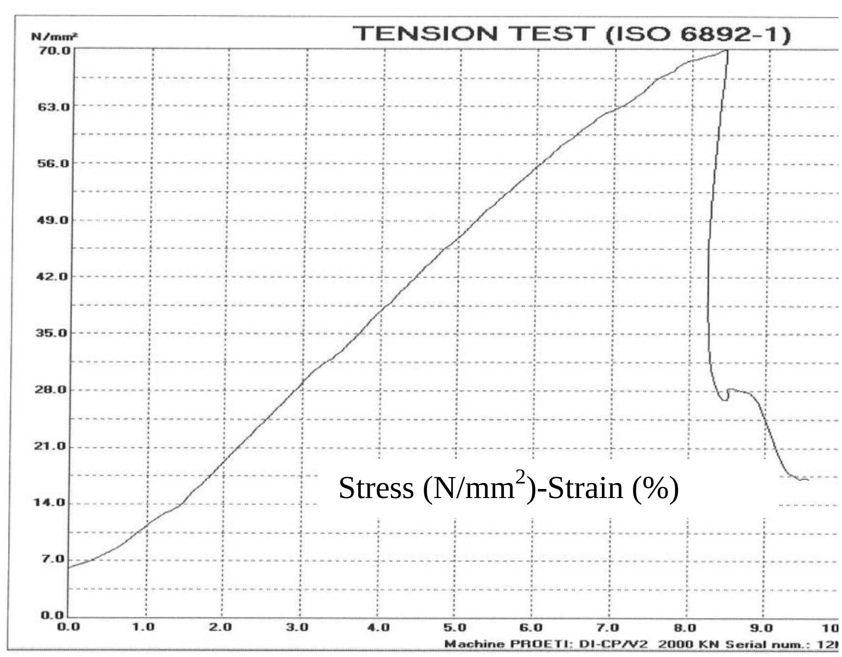


Figure 4.13: A33 (Third test for 0/90° orientation)

Generally the comparison is executed with in consideration of correction factors and by taking the average of those test results for an orientation, the strength evaluation is shown in the figure as follows:

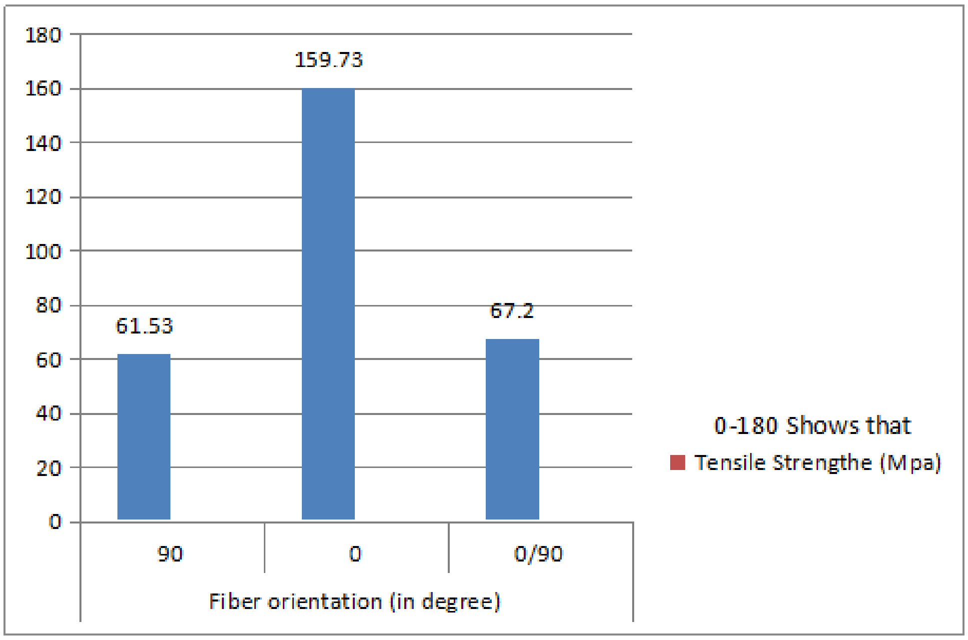


Figure 4.14: Average Tensile strength(Mpa) of different fiber orientation

Figure 4.15: Tensile test specimen after test

4.1.2. Compression test

The second test performed in this work to characterize the mechanical properties of bamboo fiber to polyester resin composite is compression test. This test is executed based on the standard and dimension shown in figure 4.16.

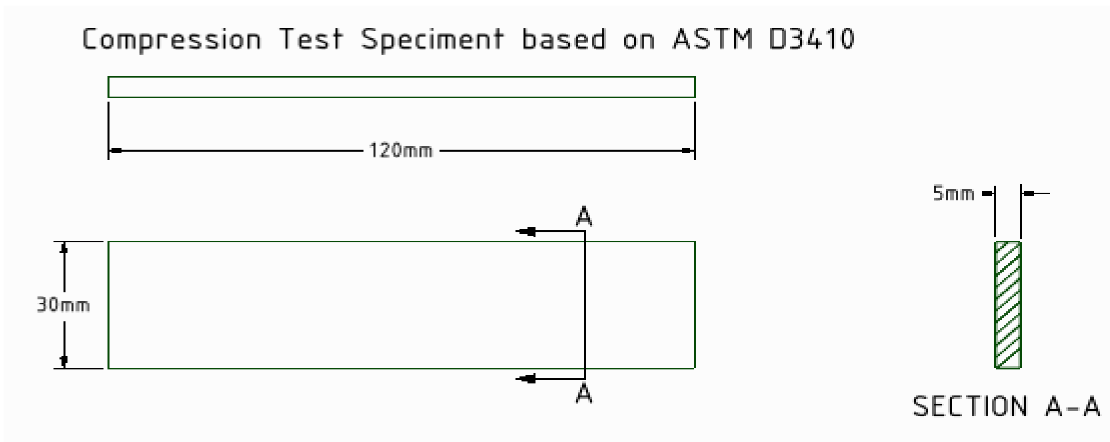


Figure 4.16: Compression test Specimen parameter

Figure 4.17 shows the compression test setup used in this thesis work which is found in Belayab Cable Factor, Adama.

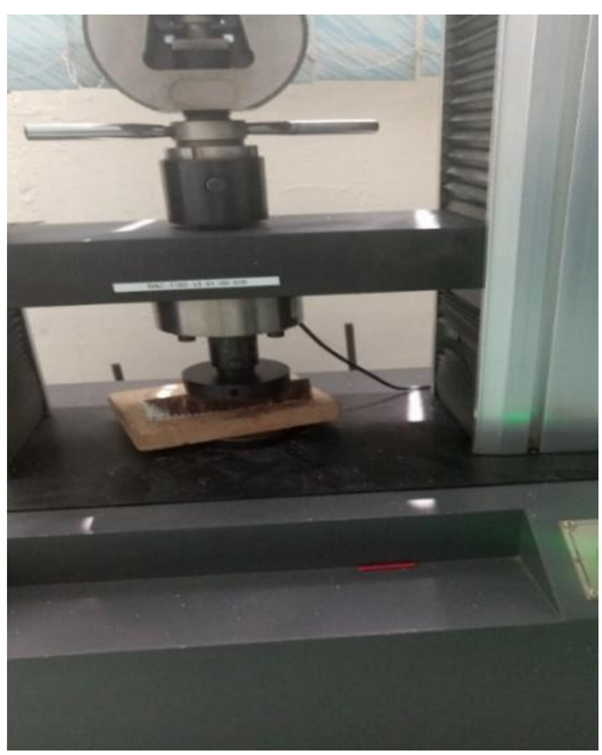


Figure 4.17: Compression test setup

As this test machine doesn't have proper output display system, it is not possible to have any print out or hard copy. So the test data is captured as a photo from a small display unit.

Figure 4.18show that the compressive strength of 90^0 bamboo fiber oriented composite material as 279.2Mpa. In this composition the maximum breaking load 28.34kN is observed at a deformation of 2.08mm and it fails after the extension of 2.63mm at a corresponding load of 7.01kN.

Figure 4.18: A1 compression test for 90° fiber orientation

Figureshows below that the load versus deformation correlation graph of the composite material.

Figure 4.19: 90° fiber composite peak load Vs deformation

Figure 4.20 belowshows that the compressive strength of 0^0 Bamboo fiber oriented composite material as 245.0 MPa. In this composition the maximum breaking load 21.32kN is observed at a deformation of 1.57mm and it fails after the extension of 1.58mm at a corresponding load of 6.44kN.

Figure 4.20: A2 (compression test for 0° fiber orientation)

- ❖ Load (kN) to materials deformation (mm) relationship property is displayed in figure 4.21

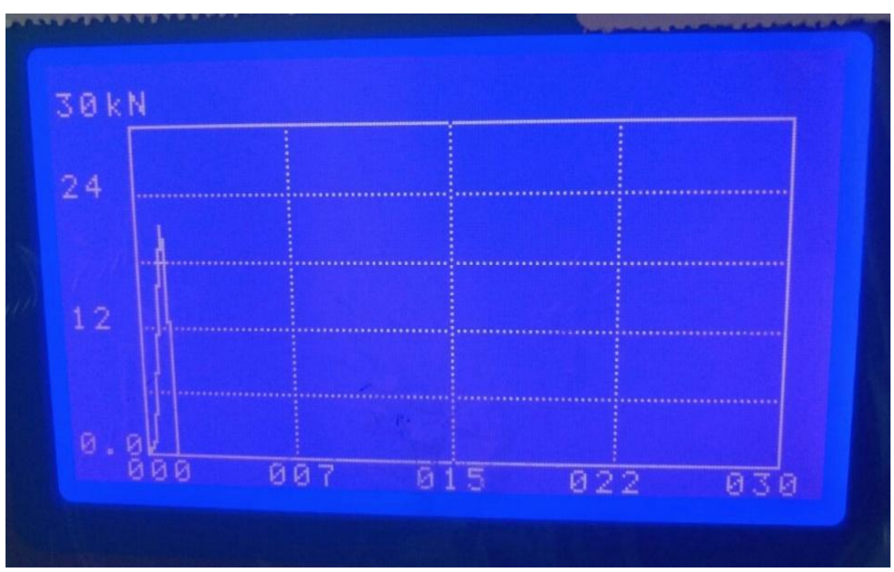


Figure 4.21: 0° fiber orientation composite peak force (KN) Vs deformation (mm)

For the case of 0/90^0 fiber orientation composite material, it has a maximum value of deformation at a smaller load when compared with previously discussed material types. 0/90^{0}fiber orientation composite material failure observed after a deformation of 2.52mm with a load of 5.96kN. This material has a compressive strength of 126.9Mpa and a peak load of 17.14kN at a deformation of 2.41mm.

Figure 4.22: A3 (compression test of 0/90° fiber orientation composite)

➢ Load versus deformation property is shown in the figure 4.23 as below.

Figure 4.23: 0/90° fiber orientation composite peak load (kN) Vs deformation (mm)

Table 4.1: Compressive properties of different fiber orientated composite

Orientation	Peak load (kN)	Deformation (mm)	Compressive Strength (Mpa)
90^0	28.34	2.08	279.2
0^0	21.32	1.57	245.0
$0/90^0$ woven	17.14	2.41	126.9

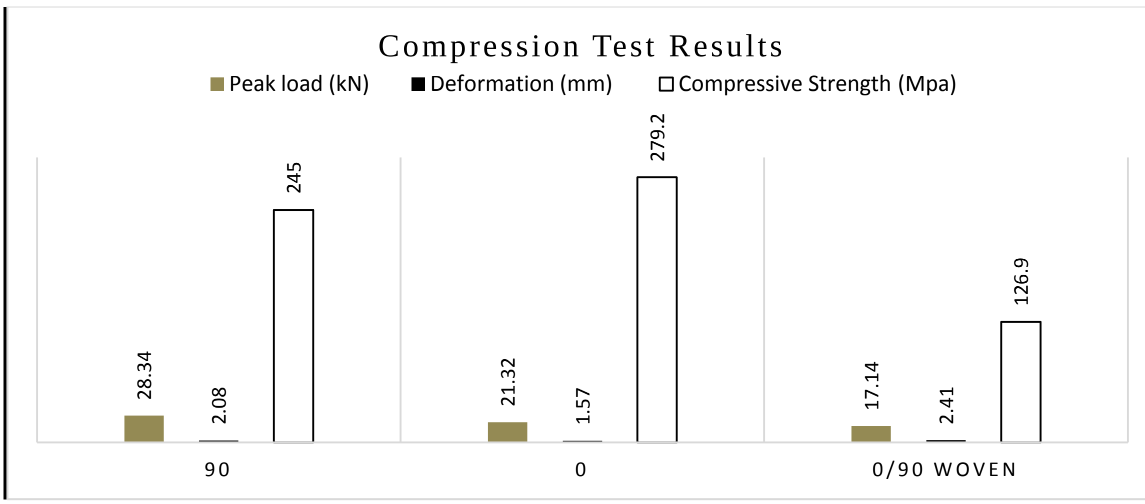


Figure 4.24: Compression test results for different fiber orientation.

4.1.3. Bending Test

The bending and compression test was examined on a universal machine in Belayab cable factory, Adama which is designed to perform both test interchangeably. As the display system is the same with compression test similar fashion of data recording is processed. Three test sample are performed and the best value out of these is taken for the analysis of this document in bending property consideration.

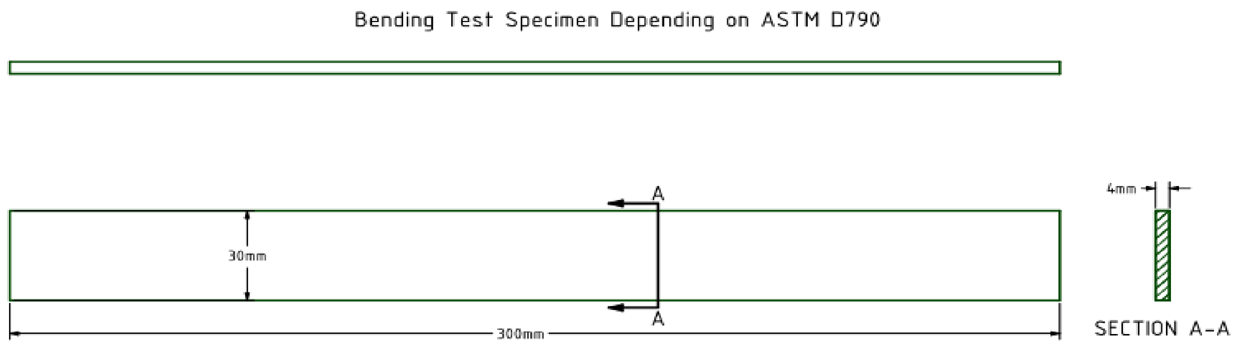


Figure 4.25: flexural test Specimen

The figure 4.25 illustrations that the universal machine with bending tests setup while the upper jaw of the machine is at the instant of downward motion. The test specimen is prepared as per the ASTM D790 standard while considering available machine specification and technicians recommendation. So, final specimen dimension is shown in the figure.

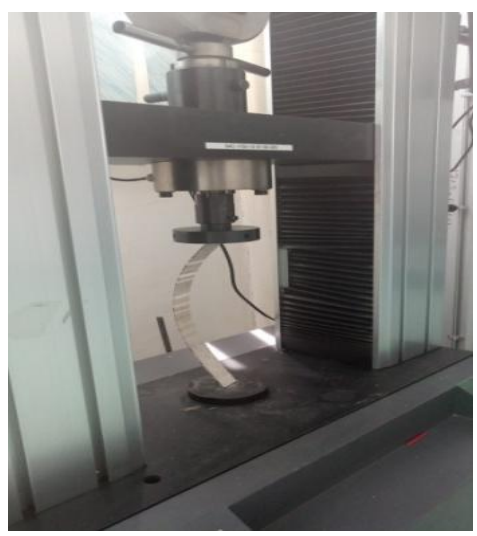


Figure 4.26: flexural test setup

Generally, this machine is applicable to test tensile, compressive and bending property of materials interchangeably. To test whether tensile, compression or bending property, simply select on the small display screen and insert parameters as per required is only ways used to differentiate those tests.

Figure 4.27: A1 90° fiber orientation flexural test

The display system demonstrates different parameters but here only some of these values are used for the analysis of this work. From the mini computer display Peak force at which the specimen is going to bend (point of bending initiation) and force at which the maximum displacement takes place are under the analysis consideration.

For 90^{o} fiber orientation composite test the peak load reading measures as 20N is applied to breakdown the test sample. The maximum displacement reaches up to 92.25 mm at the load of 40N whereas the negative sign shows the applied force vector direction.

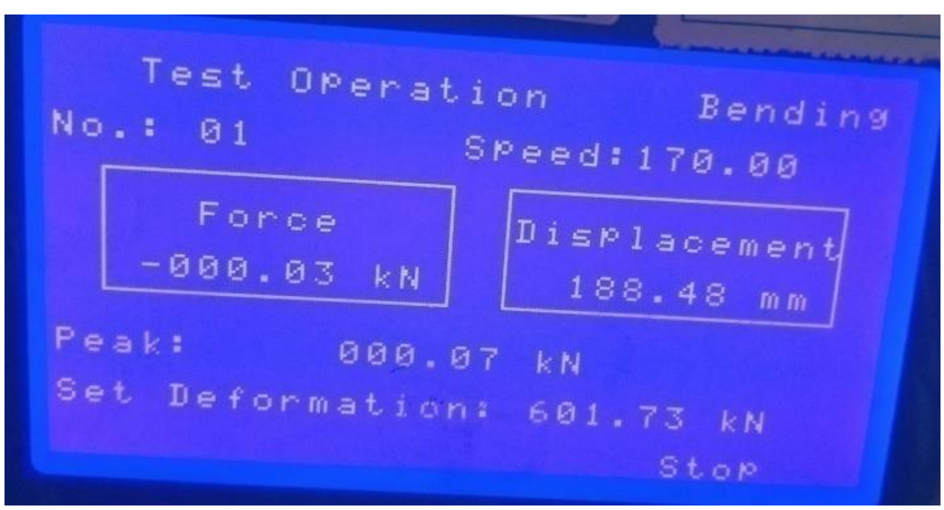


Figure 4.28: A2 0° fiber orientation flexural test

For 0^{0} fiber orientated composite, the fiber longitudinal direction and applied force vector are parallel. Test result shows that, the test specimen starts to bend early with a force of 30N but needs more force of 70N to attain the maximum deflection of 188.48mm.

Figure 4.29: A3 0/90 fiber orientation flexural test

For 0/90 fiber orientated composite, the fiber longitudinal direction and applied force vector are parallel. Test result shows that, the test specimen starts to bend early with a force of 110N but needs more force of 10N to attain the maximum deflection of 83.94mm.

Bending mechanical properties comparison for that different fiber orientation composite material is summarized as follows.

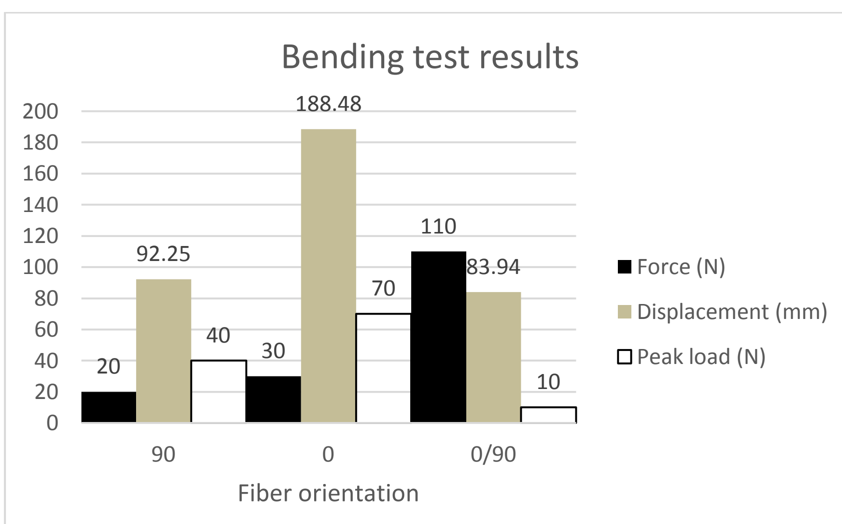


Figure 4.30: flexural test result comparisons

4.1.4 Impact test

The objective of this test work was to investigate the toughness behavior of polyester matrix composites reinforced with up to 35% in volume, continuous and 0^0 bamboo fibers orientation by means of pendulum impact tests in Debrebrehan University of laboratory section. The test samples were: 55mm x 10mm x 3.5mm (length, width, and thickness respectively) and central grooved 45^0 with 2mm depth.

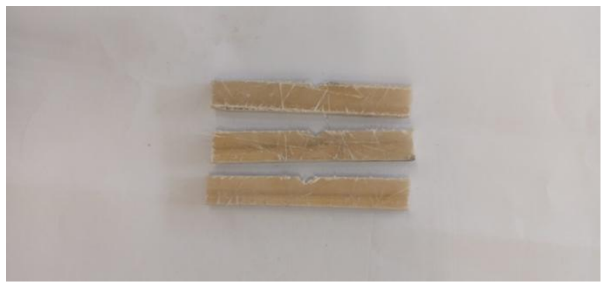


Figure:4.31 Test specimens[i]

To minimize measuring errors the lab technician calibrates the pendulum impact test machine before start the testing process.

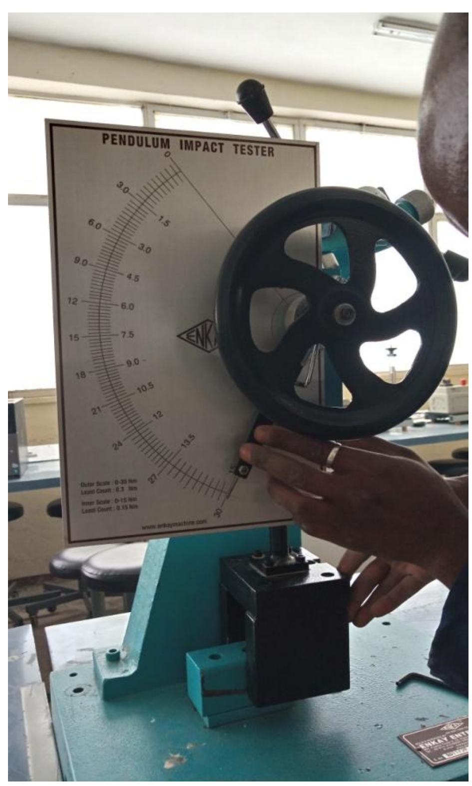
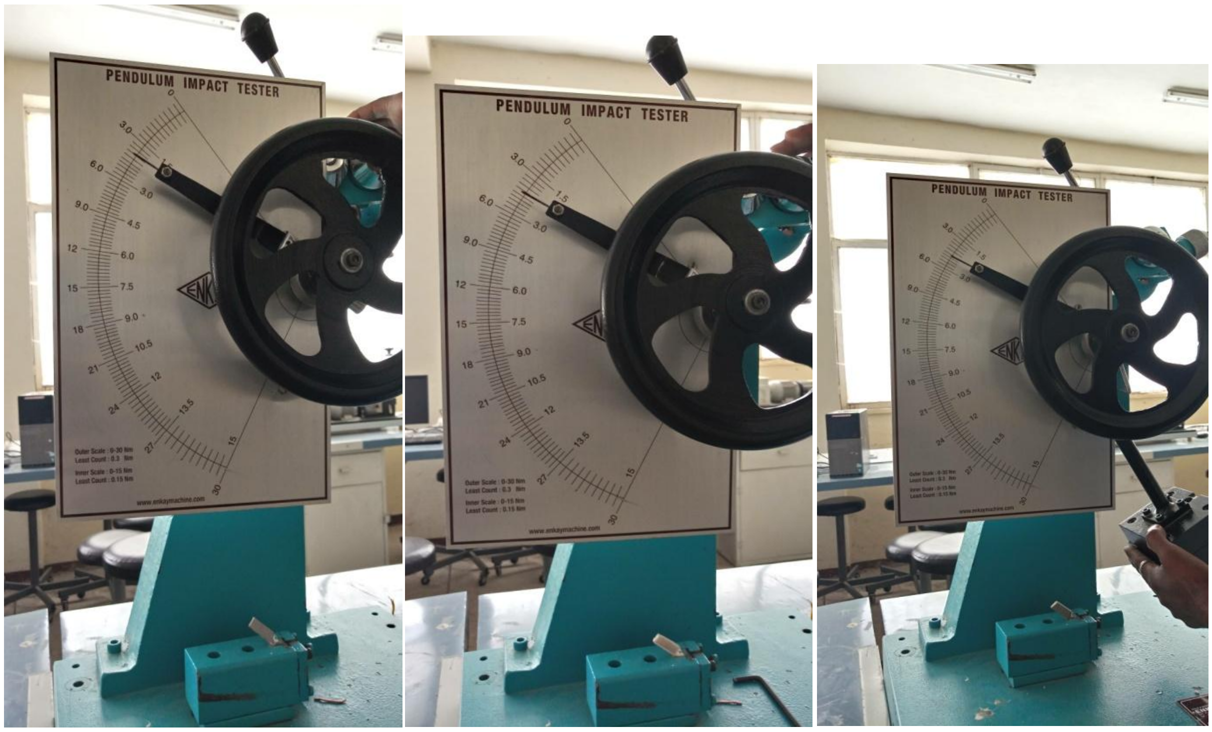


Figure:4.32 Calibration of pendulum impact test machine

The following figures show that, three samples measurement and its results:



A).first sample result B).second sample result C).third sample result

Figures: 4.33 samples measurement and its results

- The first test sample result is: **A). 3+ (5 x 0.3) = 4.5Nm.**
- The second test sample result is: **B). 3+ (6 x 0.3) = 4.8Nm.**
- The third test sample result is: **C). 3+ (7 x 0.3) = 5.1Nm.**

Depends on the result of the above samples test, the average value is:

- ✓ **4.5Nm + 4.8Nm + 5.1Nm = 14.4Nm.**
- ✓ Then the **average value** of the sample result was calculated as: **14.4Nm / 3 = 4.8Nm.**

The following figure shows that; Sample Specimens after impact test action take place.

Figure: 4.34 Sample Specimens after impact test

4.1.5 Water Absorption test

The water absorption of extracted bamboo fibers was calculated using Eq. 1 (Ishak *et al.*2013). The weight of a bunch of extracted fibers was weighed per portion and recorded equally before being immersed in distilled water as M_o. The immersed bamboo fibers in the distilled water were removed every 24 h, wiped off with filter paper, and then weighed continuously... Subsequently, the samples' weights were measured, and recorded separately from every other portion of the four bamboo species,

$$\text{Water absorption } (W_A) = ((M_t - M_o)/M_o) \times 100 \quad \text{……………………..…………4.1}$$

Where, M_t is the mass of fibers after soaking in water at different time intervals and M_o is the mass of fibers before soaking in water.

According to the above equation,measured data calculation has been taken from48hours results;

1). 90°: Initial weight = 9.8600g ⟶ Final weight = 10.3468g

2). 0°: Initial weight = 14.4221g ⟶ Final weight = 15.1173g

3). 0/90°: Initial weight = 14.8792g ⟶ Final weight = 15.4716g

Solution:-

1). (10.3468-9.8600) / 9.8600 x 100 = 0.4868/9.8600 x 100 = 4.9%

2). (15.1173 – 14.4221) / 14.4221 * 100 = 0.6952 / 14.4221 * 100 =4.8%

3). (1.4716 – 14.8792) / 14.8792 * 100 = 0.5924 / 14.8792 * 100 = 3.98 % ≈ 4%

Water Absorption Graph

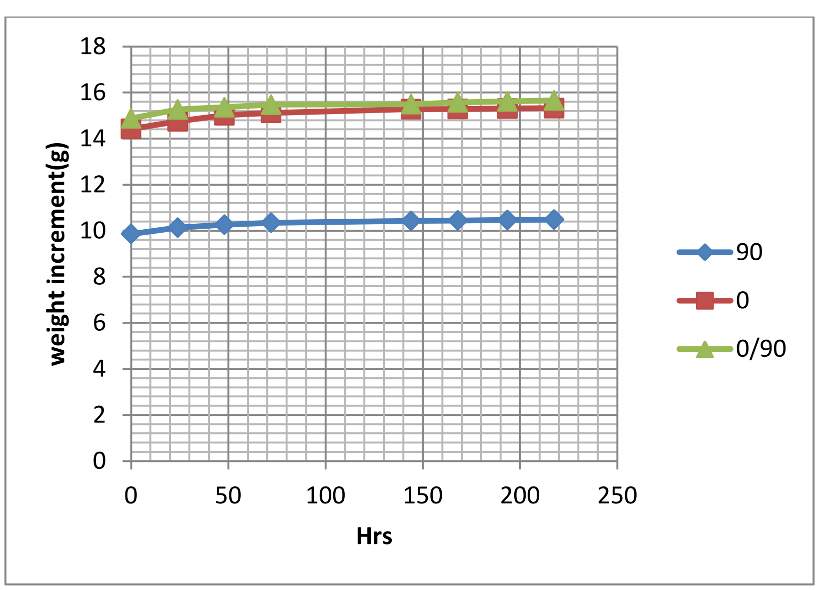


Figure: 4.35 Water Absorption

4.2 Fabrication of bamboo composite door

Based on the results obtained from the mechanical and physical laboratory test of bamboo composite tensile, compression, bending and water absorption concluding that it is best to manufacture vehicle body door panel; that have relatively 0(zero)degree fiber orientation exhibited good strength in all mechanical properties.In addition to this, the choice of the fabric for this specific research art work is basically focusing at the Ethiopian bamboo fiber and the researches which have formerly finished on it. Based on the ones measures, the composite with 30-35% bamboo fiber and 65-70 % polyester resin modified into decided on. To fabrication of three-wheel Bajaj bamboo composite door, the following activities have been done step by steps.

4.2.1 Preparation of sheet metal mold

A). Design of Sheet Metal Products

- Sheet metal part design typically proceeds as follows: in a CAD environment, a designer interprets the functional and geometric constraints of a part and creates a form representation with appropriate line types, group, and layer information; different line types are used to distinguish boundary lines. When producing in unit quantities, a single mistake in design can double the cycle time and cost of the part.
- Select proper size of thickness, length and width (2mm x 2000mm x 1000mm respectively); fixed the sheet metal on working bench applying c-clamps and vice grips.
  [Show appendix- figure A.1: fixing sheet metal on work bench].

B). Layout Planning

The layout of metal is the procedure of measuring and marking material for cutting,drilling, or welding. Accuracy is essential in layout work.

Lines are drawn on sheet metal with a scribe or scratch awl, coupled with a straightedge. To obtain the best results in scribing, first cover the area to be scribed in a very thin layer of layout dye, then hold the straightedge firmly in place and set the point of the scriber as close to the edge of the scale as possible by angling the top of the scriber outward.

[**For more refer in appendix- figure A.2: Lines drawn on sheet metal].**

C).Cutting

According to precedence diagram of sheet metal fabrication process, the model and measurement indicators can be constructed.

The cutting sequence can be determined, taking into account all constraints inherent to the cutting process. Production planning of the cutting process is based on the ability to fill up sheets with waste material minimization as the driving factor.

Various types of hand shear and cutting machines are used for cutting sheet metal. Hand scissors are necessary because the shape, construction, location, and position of the work to be cut frequently prevent the use of machine-cutting tools.

[**For more refer in appendix- figure A.3: sheet metal cutting process].**

- ❖ Finally developed door plate mold was done.

  [**For more refer in appendix- figure A.4: final mold plate].**

4.2.2 Fabrication of Composite material door

Follow up the steps which indicated above the Procedure of Fabrication of bamboo composite. The only different is put prepared mold sheet metals in the begging above main thick pressure plate and after final layer under top thick pressure plate.

The following flow chart helps to summarized and batter understanding of fabrication process for bamboo composite.

4.2.2.1 Process Flow Chart of Bamboo Composites Laminate

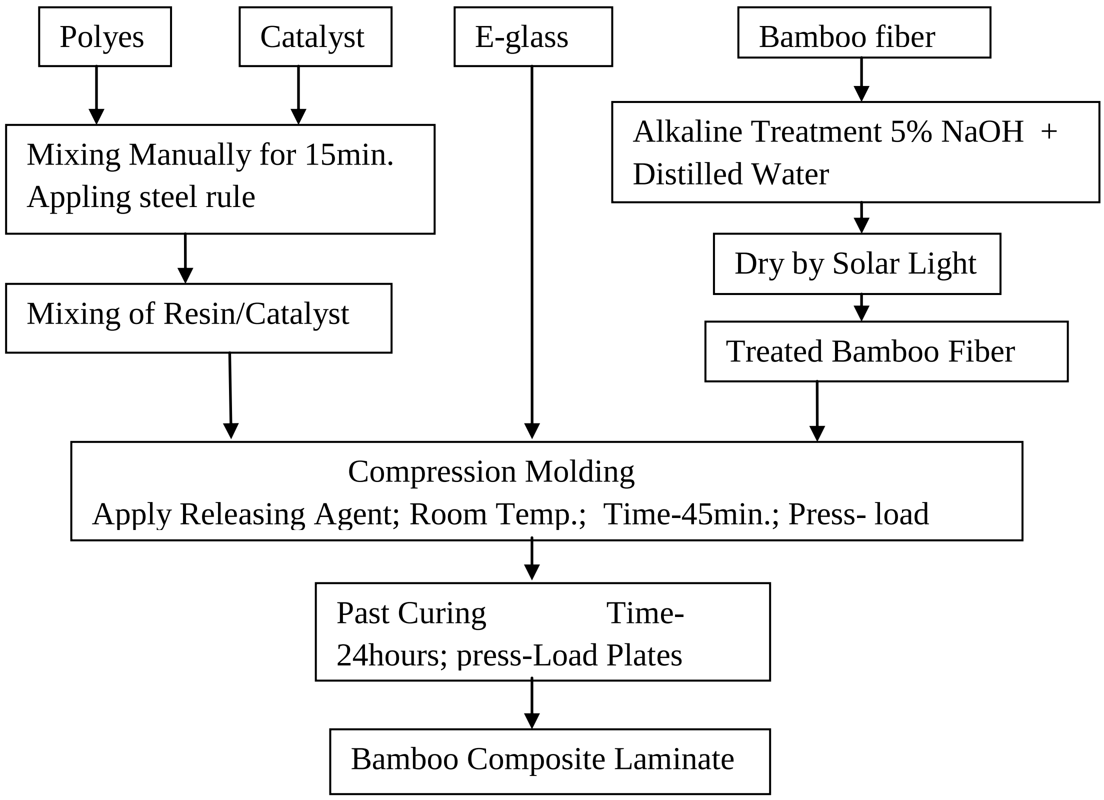


Figure 4.40: Bamboo composite door Fabrication for three wheeler

4.2.3 Shaping of door from composite laminate

The cured composite laminate is separated, the model is removed, and the tool surface cleaned using scrapers to remove mold release agent residue. The finished tool can be polished or plated to achieve the desired surface finish. **[For more refer in appendix- figure A.5: mold refinishing process].**

Final surface finish works includes:

- Applying body filler and putty to filling small dents and scratches. Strengthen frame edges with 40mm width and 4mm thickness striped bamboo composite itself.
  [For more refer in appendix-figure A.6 & A.7: preparation of strengthen frame edge strips & Final door products respectively].

4.3 Cost Analysis and Comparison

Table: The analysis of current cost of the materials in the market.

S/No	Materials	quantity	Unit	Unit price in Birr	Total Cost
1	Resin GP	1.5	kilogram	117x1.5	175.5
2	Catalyst	0.015	kilogram	(0.015x452)/0.25	27
3	Wax	0.125	kilogram	(0.125x300)/1	37.5
4	NaOH	0.037	liters	(0.037x500) /1	18.5
5	Bamboo	0.2	Roll	(150x0.2) /1	30
6	Labor Cost	-	-	estimation	30
7	Electrical Cost	-	-	estimation	10
8	Profit	Per door	Pcs	100	100

:

Table 4.2: Fabrication Comparison of three wheel Bajaj door types.

S/N	Types of Door	Cost in Birr	Weight in Kilogram(kg)	Safety&durability
1	Curtain	400	2.2	poor
2	Sheet Metal	1200	5	Best
3	Bamboo Composite	**428.5**	2.8	Best

CHAPTER FIVE

5 CONCLUSION AND RECOMMENDATION

5.1 Summary

- Composite materials may be made of natural fibers and polymer matrix with synergistic properties, improving their strength and durability.
- The bamboo plant which we find in many high lands of Ethiopia is an ideal natural fiber source for the production of door panel from natural fiber composite material.
- The safety, fuel performance and emission laws of the passenger cars are crucial issues inside the modern-day global.
- Matrix is a material which holds the fibers together. It helps to maintain the distribution of fibers and provides better finish to final product.

5.2 Conclusion

Based on the tensile, compression, bending analysis and water absorption properties experiment data studies in this work, few points can be concluded as follows:

- From the experiment result it was observed that different orientation of fiber has shown enhanced mechanical properties of the bamboo fiber composite material.
- From the Tensile Experimental test results it was found that 0° treated bamboo fiber reinforced unsaturated polyester resin composite have better tensile strength than 90° and 0/90°.
- From the Compression Experimental test results it was found that 90° treated bamboo fiber reinforced unsaturated polyester resin composite have better tensile strength than 0° and 0/90°
- From the bending Experimental test results it was found $0^0/90^0$woven treated bamboo fiber reinforced unsaturated polyester resin composite have better bending strength than 0° and 90°.
- The effect of moisture content obtained from water absorption test is within the specifications and has minimum water absorption for auto body door panels.

- From water absorption tests results of each specimen with 90^0 fiber orientation has 4.9 % which is lower than other two fiber arrangements of 4.8 % (0-degree) and ≈ 4% (0/90° degree). In these test all of the specimens' fiber orientations have minimum water absorption which is less than15 % of ASTM C220 standards.
- Considering the simplicity of the process and no demand of additional accessories the hand layup technique is found to be the best way to produce the sample composite materials as well as the prototype door.
- Producing a door panel from bamboo fiber composite material has benefits of reducing cost, enhance customer satisfaction, decrease fuel consumption and significantly could substitute imported raw materials for the door panel.

5.3 Recommendations for Prospective Applications

- Bamboo fiber reinforced unsaturated polyester resin composite materials are appropriate for structural automotive applications, such as interior and exterior body panels and carry out to a comparable standard as steel components.
- Bamboo fiber reinforced unsaturated polyester resin composites were fabricated and evaluated for their mechanical and physical characteristics. From this investigation, it has been found that sufficient potential applications are found in the following fields: manufacturing of light weight sports goods such as, tennis rackets, balls, bicycle frames, snowboards, Spur and helical gears etc.
- The present study have recognized that these bamboo fiber reinforced unsaturated polyester resin composites are used when cost reduction is the prime reflection, and can effectively replace the conventional and relatively expensive materials. Their use may be recommended in house hold applications like the fabrication of tables, chairs, door panels, interior paneling, door-frame profiles, food trays, partitions, bath units, lampshades, suitcases, helmets, etc.
- Production of some other vehicle structure that may be substituted by means composite material and display the comparable advantage of bamboo fiber composite to the auto enterprise, the educational area and to the government.

5.4 Future scope of research

From different aspects, working on natural composite materials has several advantages. From this point of views, regarding BFREC several things can be made and improved in the future in which this study didn't address.

Therefore; the following research areas are recommended for future studies.

- Repeat the design and fabrication of three wheel Bajaj roof by using other forms bamboo fiber composite.
- Applying of BFREC on other external parts of the three wheel vehicle body panels.
- Design and fabricate bamboo composite three wheel door Applying mass product to distribute the whole regional states.

6 REFERENCE

[1]. Alen John, Sanu Alex, “A review on the composite materials used for automotive bumper in passenger vehicles”, Volume-4, Issue-4, pp. 98-101, August-2014..

[2]. O.M. Terciu, I. Curtu, C. Cerbu; “FEM modeling of an automotive door trim panel made of lignocelluloses composites in order to determine the stresses and displacements in case of a door slam simulation”; The 4th International Conference of Advanced Composite Materials Engineering, COMAT 2012, Brasov, Romania, (2012)

[3]. Mr. SandeepBundele& Dr. Rupa S. Bindu; “Automotive Door Design and Structural Optimization of Front Door for Commercial Vehicle with ULSAB Concept for Cost and Weight Reduction”; Global Journal of Researches in Engineering (Automotive Engineering); Volume 12 Issue 2 Version 1.0 (2012)

[4]. Tan Wei, Wang Yan, Li Lingyang, Zhang Yu; “Design of the Vehicle Door Structure Based on Finite Element Method”; The 2nd International Conference on Computer Application and System Modeling; Wuhan, China (2012)

[5]. TawandaMushiri, and Charles Mbohwa; “Design of a Vehicle Door Structure Based on Finite Element Method”; 6th International Conference on Mechanical, Production & Automobile Engineering (ICMPAE); Cape Town (South Africa); 2014

[6]. Said Darwish, H. M. A. Hussein and Ahmad Gemeal; “Numerical Study of Automotive Doors” International Journal of Engineering and Technology IJET -IJENS Vol: 12 No☹ (04): 82–92. Das, S., 2015

[7]. M. Raghuveer, GantiSatyaPrakash; “Design and Impact Analysis of a Car Door”; International Journal of Modern Engineering Research (IJMER); Vol. 4 Iss.9; 2014

[8]. Enrico Mangino, Joe Carruthers and Giuseppe Pitarresi; “The future use of structural composite materials in the automotive industry”; NewRail, School of Mechanical and Systems Engineering, University of Newcastle upon Tyne, NE1 7RU, UK

[9]. ErmiasGebrekidanKoricho, “Implementation of composite and plastics materials for vehicle light weight”; PH.D Thesis, 2012, p 44-74.

[10]. Chandrasekhar V et al. 2014 *Inter. J. of Eng. Res. and Tech.* **3** 132-134

[11]. Roslan S et al. 2015 *Int. J. Automot. Mech. Eng* **12** 2882-2892

[12]. Zhang X, Wang F and Leon M 2015 *Materials (Basel)* **8** 6597-6608

[13]. Nassar, A & Nassar, E 2013, 'Study on Mechanical Properties of Polyester Polymer Reinforced with NanoSiC particles'.

[14]. EsmaelAdem et.al.; “Experimental Analysis of E-Glass /Polyester& E-Glass /polyester Composites for Auto Body Panel” AIJRSTEM; 2015, pp. 377-383

[15]. Anokye R, Bakar NN, Bakar ES, Ratnasingam J, Yong ACC. The effects of nodes and resin on the mechanical properties of laminated bamboo timber produced from Gigantochloascortechinii. Construction and Building Materials 2016;105:285–90. 030046

[16]. Al-Bahadly EAO. The Mechanical Properties of Natural Fiber Composites Melbourne, Australia: Swinburne University of Technology; 2013.

[17]. Kumar V, Kumar R. Dielectric and mechanical properties of alkali- and silane-treated bamboo-polyester nanocomposites. Journal of Composite Materials. 2012;46(24):3089–101

[18]. FekaduTarekegne and Philip Conze, “Study of Ethiopia high land bamboo composite for structural materials” Commissioned by Fortune Enterprise P.L.C collaborated with GTZ on a public private partnership project (PPP), 2011, Addis Ababa, Ethiopia

[19]. AbiyAlene: “Design and Analysis of Bamboo and E-Glass Fiber Reinforced Polyester Hybrid Composite for Wind Turbine Blade Shell”; MSc thesis, AAiT, SMIE, 2013.

[20]. S. A. H. Roslan, Z. A. Rasid and M. Z. Hassan; “The Natural Fiber Composites Based on Bamboo Fibers: A review”; ARPN Journal of Engineering and Applied Sciences; VOL. 10; No. 15; 2015.

[21]. S. Sreenivasul u, Dr. A Chennakeshava Reddy; “Mechanical Properties Evaluation of Bamboo Fiber Reinforced Composite Materials”; International Journal of Engineering Research, Volume No.3 Issue No: Special 1; pp: 187-194; 2014

[22]. Syed AltafHussain, Dr. V.Pandurangadu, Dr. K.Palanikuamr; “Mechanical properties of short bamboo fiber reinforced polyester composites filled with alumina particulate”; IRACST – Engineering Science and Technology; An International Journal (ESTIJ); Vol. 2; No. 3; 2012

[23]. Subhash Kumar Gupta, Prof. SandhyaraniBiswas; “A study on mechanical behavior of bamboo fiber based polymer composites”; National Institute of Technology, Rourkela; 2014

[24]. D.Dash, S.Samanta, S.S. Gautam, and M. Murlidhar; "Mechanical Characterization of Natural Fiber Reinforced Composites Materials"; Advanced Materials Manufacturing and Characterization; Vol. 3 Issue 1; (2013).

[25]. Dheeraj Kumar (Asstt. Prof.); "Characterization of tensile properties of treated bamboo natural fiber polymer composite"; International Journal of Mechanical Engineering and Technology (IJMET); Volume 5; Issue 4; (2014), pp. 110-115.

[26]. Vivek Kumar, SanatMohanty; "High Performance Moldable Bamboo Fiber-Polyester Composites"; Indian Institute of Technology, Delhi; (2012)

[27]. Honey Banga ,V.K. Singh , Sushil Kumar Choudhary, "Fabrication and Study of Mechanical Properties of Bamboo Fibre Reinforced Bio- Composites", Innovative Systems Design and Engineering, Vol.6, No.1, 2015.

[28]. AgusEdyPramono ,IndriyaniRebet, Anne Zulfia, Subyakto, " Tensile and Shear Punch Properties of Bamboo Fibers Reinforced Polymer Composites", International Journal of Composite Materials 2015.

[29]. Navdeep Sharma, Sameer Sharma, S.P. Guleria, N.K. Batra, "Mechanical Properties of Urea Formaldehyde Resin Composites Reinforced with Bamboo, Coconut and Glass Fibers", International Journal of Soft Computing and Engineering , ISSN: 2231-2307, Volume-5 Issue-2, May 2015.

[30]. Shinji Ochi, "Tensile properties of bamboo fiber reinforced biodegradable plastics", International Journal of Composite Materials, ISSN 2166-4919, Vol. 2, Issue 1, pp.1-4, 2012.

[31]. G. MeenambikaBai, H. RaghavendraRao, Mechanical and Chemical Properties of Bamboo/Glass Fibers Reinforced Polyester Hybrid Composites, Industrial Engineering Letters, Vol.4, No.4, 2014.

[32]. Hemalata Jena, Mihir Ku. Pandit, and Arun Ku. Pradhan, "Study the Impact Property of Laminated Bamboo-Fibre Composite Filled with Cenosphere", International Journal of Environmental Science and Development, Vol. 3, No. 5, October 2012.

[33]. Mr. Vikram. S Yendhe, Mr. Nilesh B. Landge, Mr. Manoj B. Thorat, Development and Investigation of Mechanical Behaviour of Bamboo Based Fiber Composites, International Journal for Research in Applied Science & Engineering Technology, Vol. 3, Issue-6, June 2015

[34]. RaghavendraYadavEagala, AllakaGopichand, GujjalaRaghavendra, Sardar Ali S, Abrasive Wear Behaviour of Bamboo-Glass Fiber Reinforced Polyester Composites Using Taguchi Approach, International Journal of Advances in Engineering & Technology, Vol. 5, Issue-1, pp: 399-405, November 2012.

[35]. RaghavendraRao, Y. Indraja, G. MeenambikaBai, Flexural Properties and Sem Analysis of Bamboo and Glass Fiber Reinforced Polyester Hybrid Composites, IOSR Journal of Mechanical and Civil Engineering, Vol. 11, Issue-2, pp: 39-42, April 2014.

[36]. Osorio L, Trujillo E, Van Vuure AW, Verpoest I. Morphological aspects and mechanical properties of single bamboo fibers and flexural characterization of bamboo/ epoxy composites. J Reinf Plast Compos. 2010; 30(5):396-408.

APPENDIX

A).Tables from letricher review about designation of weighting, composition and fiber orientation of composites.

Table: Designation and weighting of Composites

Samples	Composition
PB-1	Polymer + Bamboo Fiber (15 wt %)
PB-2	Polymer + Bamboo Fiber (30 wt %)
PB-3	Polymer + Bamboo Fiber (45 wt %)
PBA-1	Polymer + Bamboo Fiber (45 wt %) + Alumia (0 wt %)
PBA-2	Polymer + Bamboo Fiber (15wt %) + Alumia (5 wt %)
PBA-3	Polymer + Bamboo Fiber (15wt %) + Alumia (10 wt %)

Table: Designation and composition of Composites

Samples	Composition
PB-1	Polymer + Bamboo Fiber (15 wt %)
PB-2	Polymer + Bamboo Fiber (30 wt %)
PB-3	Polymer + Bamboo Fiber (45 wt %)
PBA-1	Polymer + Bamboo Fiber (45 wt %) + Alumia (5 wt %)
PBA-2	Polymer + Bamboo Fiber (45wt %) + Alumia (10 wt %)
PBA-3	Polymer + Bamboo Fiber (45wt %) + Alumia (15 wt %)

Table: Composition and designation of fiber reinforced composites

Composite	Composition
C-1	Polyester (90 wt.%) + Short bamboo fiber of length 4mm (10 wt.%)
C-2	Polyester (80 wt.%) + Short bamboo fiber of length 4mm (20 wt.%)
C-3	Polyester (70 wt.%) + Short bamboo fiber of length 4mm (30 wt.%)
C-4	Polyester (90 wt.%) + Short bamboo fiber of length 4mm (10 wt.%)
C-5	Polyester (80 wt.%) + Short bamboo fiber of length 4mm (20 wt.%)

C-6	Polyester (70 wt.%) + Short bamboo fiber of length 4mm (30 wt.%)
C-7	Polyester (90 wt.%) + Short bamboo fiber of length 4mm (10 wt.%)
C-8	Polyester (80 wt.%) + Short bamboo fiber of length 4mm (20 wt.%)
C-9	Polyester (70 wt.%) + Short bamboo fiber of length 4mm (30 wt.%)

B). Also the following Different necessary store materials (facilitating tools).

C).Tensile strength of tested results

ECAE ኢ.ተ.ም.ድ	የኢትዮጵያ የተስማሚነት ምዘና ድርጅት Ethiopian Conformity Assessment Enterprise	Document No. TLD/F5.10-1	
		Copy No: -	Rev No: 1
Title:	TEST REPORT ይህ የናሙና ፍተሻ ሪፖርት እንጂ ሰርተፍኬት አይደለም	Page No: 1 of 1	Effective Date: 1Jan 13

Report No: MTR/1976/11
Test order No: ---

1	Name and address of client	Mulugeta Denanto Tel: +251-966-42-93-01, Adama
2	Date and place of sampling	Not Specified
3	Sampled and submitted by	Client
4	Date sample received	14/05/2019
5	Client's sample code	-
6	Laboratory designated sample No.	11246017,11246018 & 11246019
7	Type of sample	Composite Material (Bamboo)
8	Test method	As Per Client Agreement
9	Test date(s)	15/05/2019
10	Date of Submission of test report	15/05/2019

Test result

L.D.S. No.	Test Specimen No.	Client Code	Minimum Breadth (mm)	Minimum Thickness (mm)	Tensile Strength (Mpa)
11246017	1	A_{11}	18.75	2.75	64.6
	2	A_{12}	18.32	2.86	55.9
	3	A_{13}	18.62	2.90	64.1
11246018	1	A_{21}	18.80	3.35	155.3
	2	A_{22}	18.60	3.43	145.5
	3	A_{23}	19.53	3.51	178.4
11246019	1	A_{31}	19.45	4.30	69.5
	2	A_{32}	19.65	4.01	68.4
	3	A_{33}	19.63	4.00	63.7

Remark:

1. This test report relates only to the specific sample product which has been tested by ECAE Testing laboratory.

Test report authorized by; Name Liyew Wudie Position Analyst I Sign.

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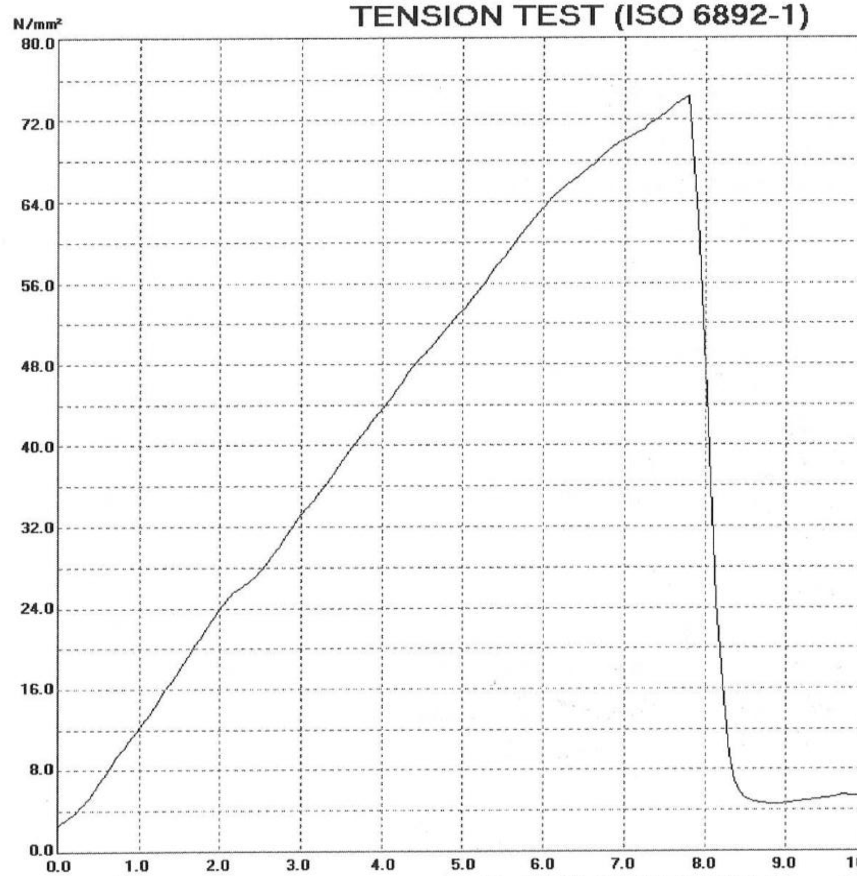
✉ 11145 ☎ 011 6 46-05-69, Fax. 011 6 45-97-20, E-mail info-cs@eca-e.com Web site: www.eca-e.com
BOLE SUBCITY, WOREDA 6
ADDISABABA, ETHIOPIA

TENSION TEST (ISO 6892-1)

ECAE Ethiopian Conformity Assessment Enterprise



Machine PROETI: DI-CP/V2 2000 KN Serial num.: 12M9993

TEST DATA

Test num	11246017-A11
Order num	
For	Mulugeta Denanto
Reference	
Material	Composite Material(Bamboo)
Inspector	Habtamu Mihret
Note 1	
Note 2	
Note 3	

SPECIMEN DATA

Specimen name			
Specimen class		Rectangle	
Thick (a)		2.75	mm
Width (b)		18.75	mm
Diam	D	0.00	mm
Gage Length	Lo	40.00	mm
Area	So	51.56	mm²

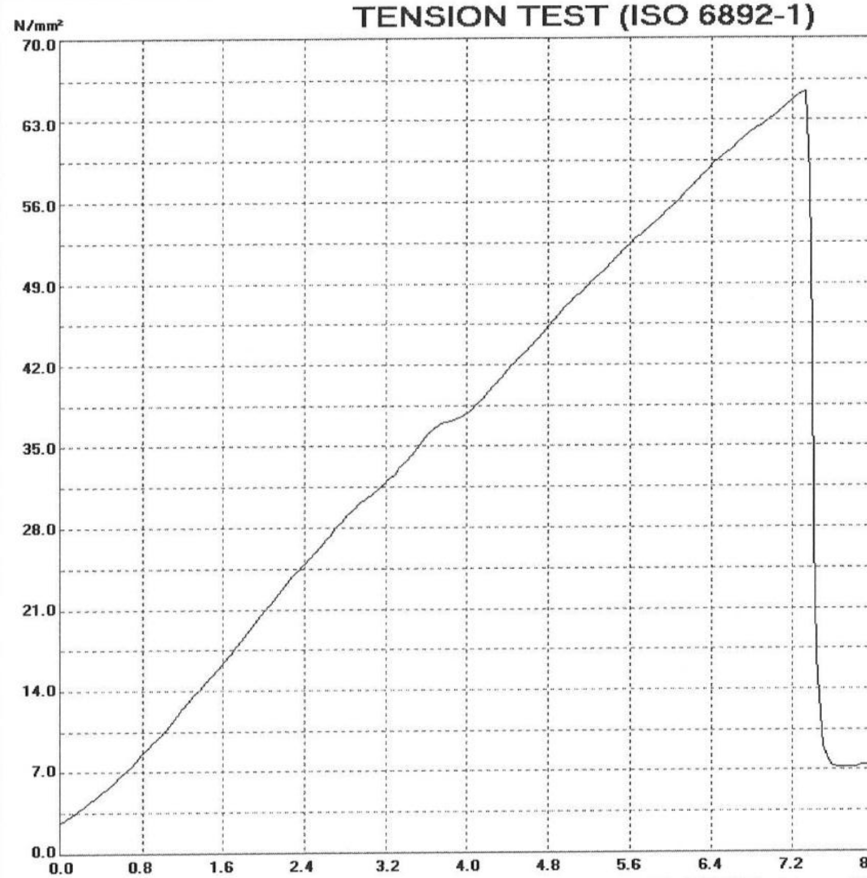
TEST RESULTS

Force max	Fm	3.83	kN.
Tensil Stress	Rm	74.3	MPa
Yield stress UYS/(ReH)		0.0	MPa
Yield stress LYS/(ReL)		0.0	MPa
Tot Elongation	A	9.5	%
Uniform Elong	Agt	7.8	%
Yield Stress	Rp(.2%)	27.1	MPa

64.6

TENSION TEST (ISO 6892-1)

ECAE Ethiopian Conformity Assessment Enterprise



Machine PROETI: DI-CP/V2 2000 KN Serial num.: 12M9993

TEST DATA

Test num	11246017-A12
Order num	
For	Mulugeta Denanto
Reference	
Material	Composite Material(Bamboo)
Inspector	Habtamu Mihret
Note 1	
Note 2	
Note 3	

SPECIMEN DATA

Specimen name			
Specimen class		Rectangle	
Thick (a)		2.86	mm
Width (b)		18.32	mm
Diam	D	0.00	mm
Gage Length	Lo	40.00	mm
Area	So	52.40	mm²

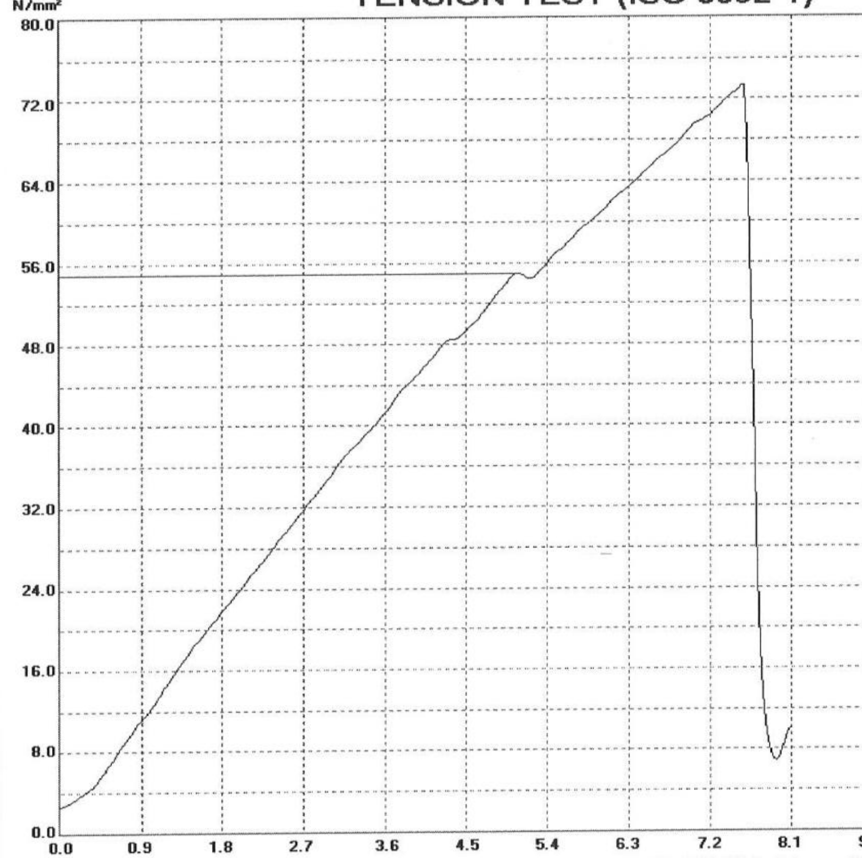
TEST RESULTS

Force max	Fm	3.43	kN.
Tensil Stress	Rm	65.5	MPa
Yield stress UYS/(ReH)		0.0	MPa
Yield stress LYS/(ReL)		0.0	MPa
Tot Elongation	A	7.2	%
Uniform Elong	Agt	7.3	%
Yield Stress	Rp(.2%)	36.9	MPa

55.9

TENSION TEST (ISO 6892-1)

Ethiopian Conformity Assessment Enterprise



Machine PROETI: DI-CP/V2 2000 KN Serial num.: 12M9993

TEST DATA

Test num		11246017-A13	
Order num			
For		Mulugeta Denanto	
Reference			
Material		Composite Material(Bamboo)	
Inspector		Habtamu Mihret	
Note 1			
Note 2			
Note 3			

SPECIMEN DATA

Specimen name			
Specimen class		Rectangle	
Thick (a)		2.90	mm
Width (b)		18.62	mm
Diam	D	0.00	mm
Gage Length	Lo	40.00	mm
Area	So	54.00	mm²

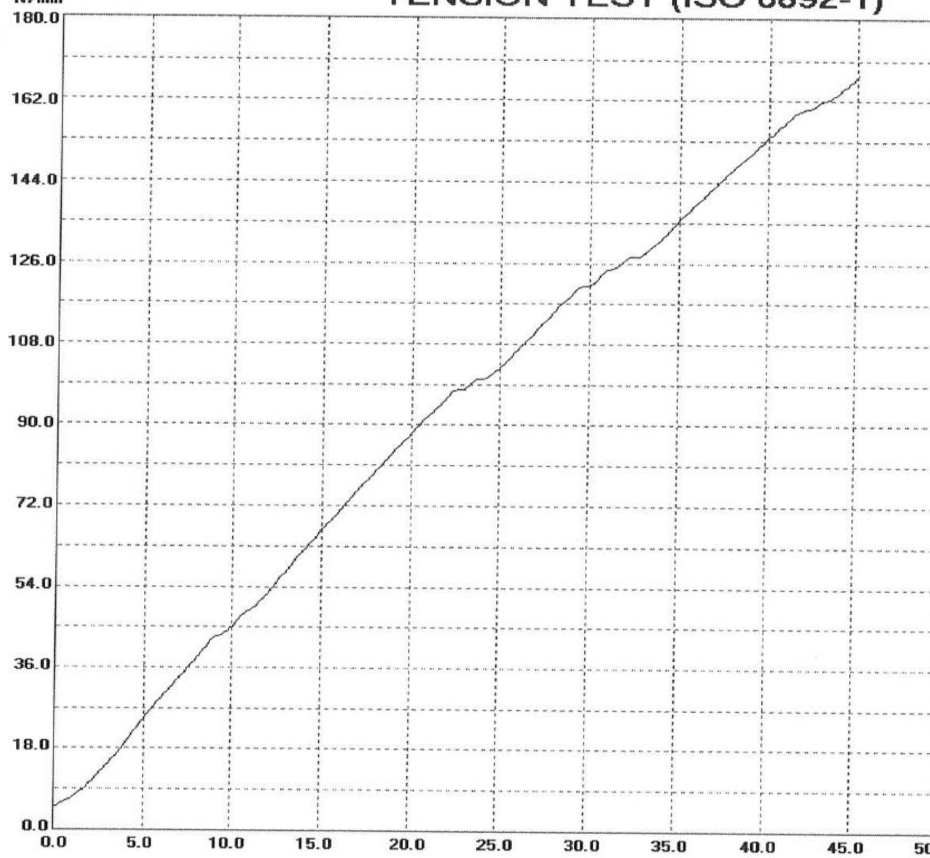
TEST RESULTS

Force max	Fm	3.96	kN.
Tensil Stress	Rm	73.3	MPa
Yield stress UYS/(ReH)		54.9	MPa
Yield stress LYS/(ReL)		54.5	MPa
Tot Elongation	A	7.3	%
Uniform Elong	Agt	7.6	%
Yield Stress	Rp(.2%)	38.3	MPa

64.1

TENSION TEST (ISO 6892-1)

ECAE Ethiopian Conformity Assessment Enterprise



Machine PROETI: DI-CP/V2 2000 KN Serial num.: 12M9993

TEST DATA

Test num	11246018-A21
Order num	
For	Mulugeta Denanto
Reference	
Material	Composite Material(Bamboo)
Inspector	Habtamu Mihret
Note 1	
Note 2	
Note 3	

SPECIMEN DATA

Specimen name			
Specimen class		Rectangle	
Thick (a)		3.35	mm
Width (b)		18.80	mm
Diam	D	0.00	mm
Gage Length	Lo	40.00	mm
Area	So	62.98	mm²

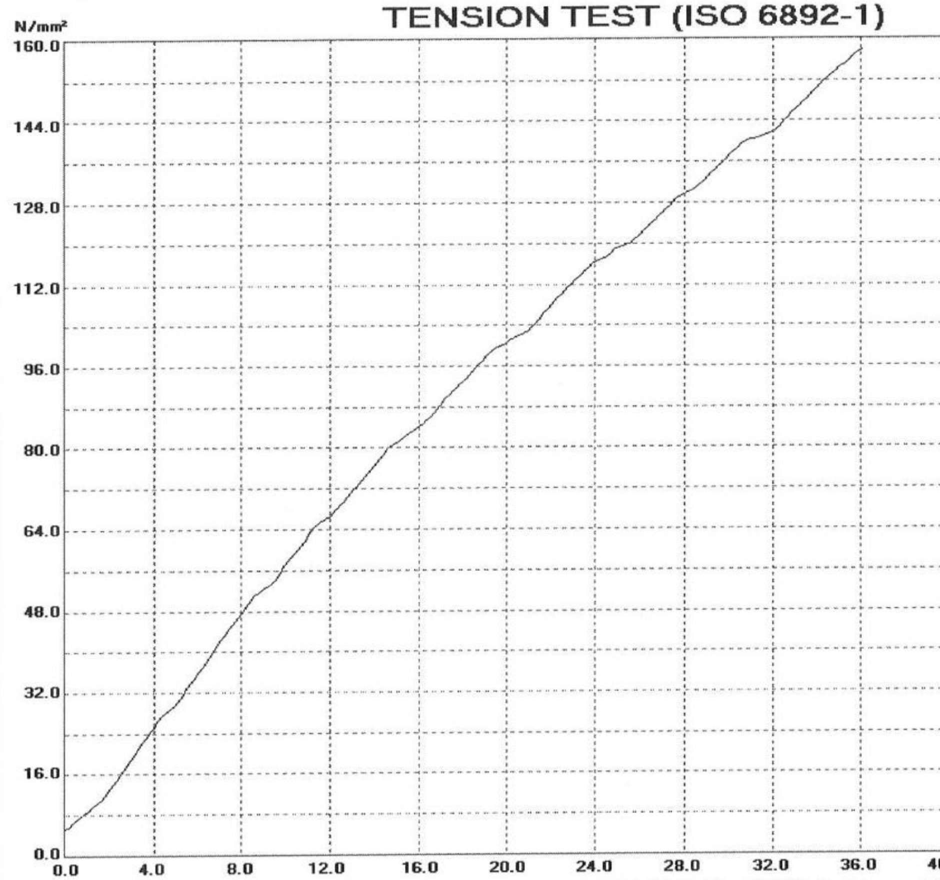
TEST RESULTS

Force max	Fm	10.58	kN.
Tensil Stress	Rm	168.0	MPa
Yield stress UYS/(ReH)		0.0	MPa
Yield stress LYS/(ReL)		0.0	MPa
Tot Elongation	A	10.3	%
Uniform Elong	Agt	45.1	%
Yield Stress	Rp(.2%)	42.7	MPa

155.3

TENSION TEST (ISO 6892-1)

ECAE Ethiopian Conformity Assessment Enterprise



Machine PROETI: DI-CP/V2 2000 KN Serial num.: 12M9993

TEST DATA

Test num		11246018-A212	
Order num			
For		Mulugeta Denanto	
Reference			
Material		Composite Material(Bamboo)	
Inspector		Habtamu Mihret	
Note 1			
Note 2			
Note 3			

SPECIMEN DATA

Specimen name			
Specimen class		Rectangle	
Thick (a)		3.43	mm
Width (b)		18.60	mm
Diam	D	0.00	mm
Gage Length	Lo	40.00	mm
Area	So	63.80	mm²

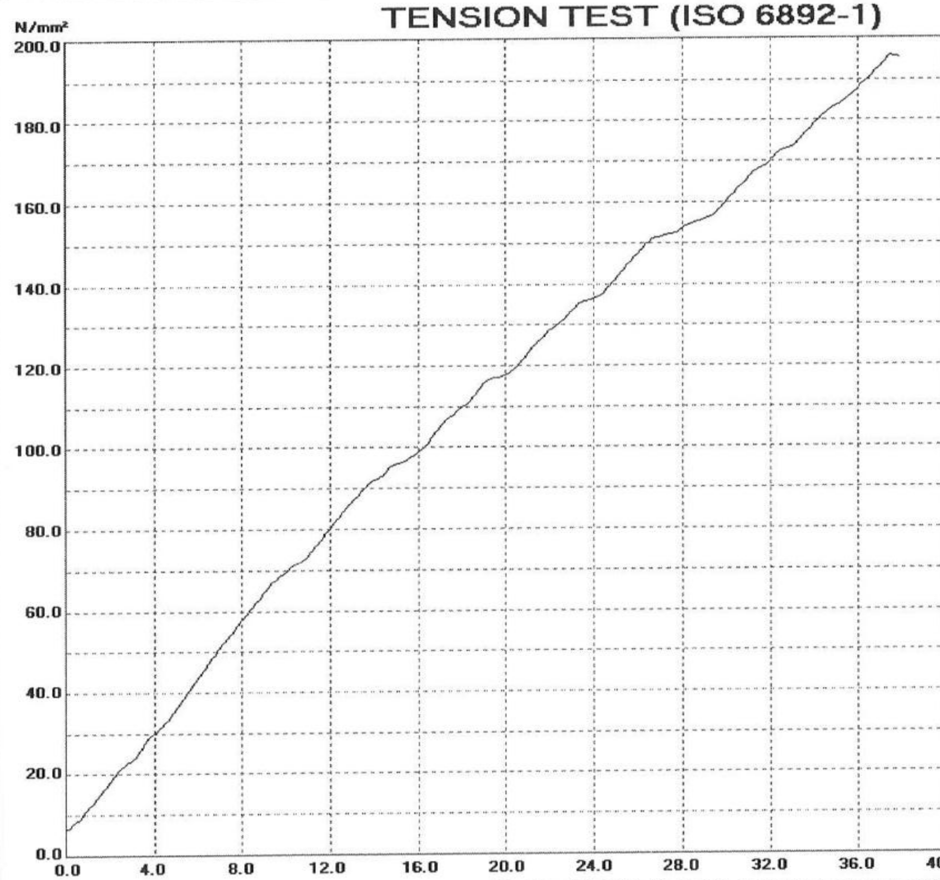
TEST RESULTS

Force max	Fm	10.08	kN.
Tensil Stress	Rm	158.0	MPa
Yield stress UYS/(ReH)		0.0	MPa
Yield stress LYS/(ReL)		0.0	MPa
Tot Elongation	A	9.6	%
Uniform Elong	Agt	36.1	%
Yield Stress	Rp(.2%)	51.6	MPa

1455.

TENSION TEST (ISO 6892-1)

Ethiopian Conformity Assessment Enterprise



Machine PROETI: DI-CP/V2 2000 KN Serial num.: 12M9993

TEST DATA

Test num	11246018-A23
Order num	
For	Mulugeta Denanto
Reference	
Material	Composite Material(Bamboo)
Inspector	Habtamu Mihret
Note 1	
Note 2	
Note 3	

SPECIMEN DATA

Specimen name			
Specimen class		Rectangle	
Thick (a)		3.51	mm
Width (b)		19.53	mm
Diam	D	0.00	mm
Gage Length	Lo	40.00	mm
Area	So	68.55	mm²

TEST RESULTS

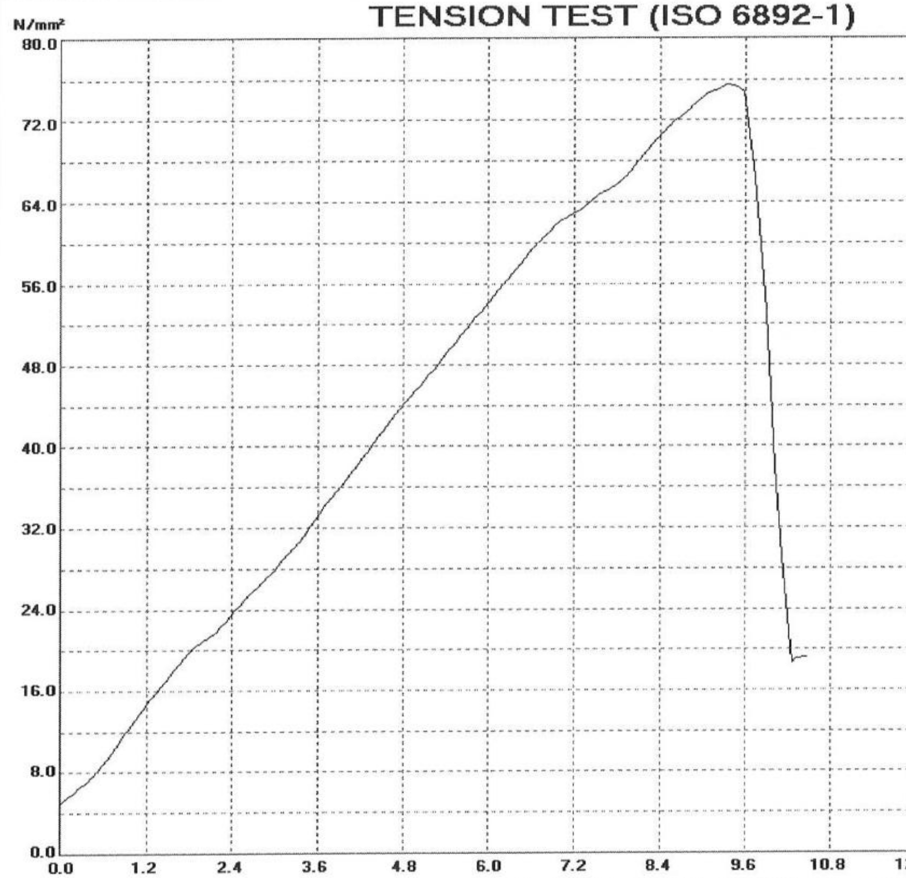
Force max	Fm	13.43	kN.
Tensil Stress	Rm	195.9	MPa
Yield stress UYS/(ReH)		0.0	MPa
Yield stress LYS/(ReL)		0.0	MPa
Tot Elongation	A	10.8	%
Uniform Elong	Agt	37.5	%
Yield Stress	Rp(.2%)	67.8	MPa

178.4

6

TENSION TEST (ISO 6892-1)

ECAE Ethiopian Conformity Assessment Enterprise



Machine PROETI: DI-CP/V2 2000 KN Serial num.: 12M9993

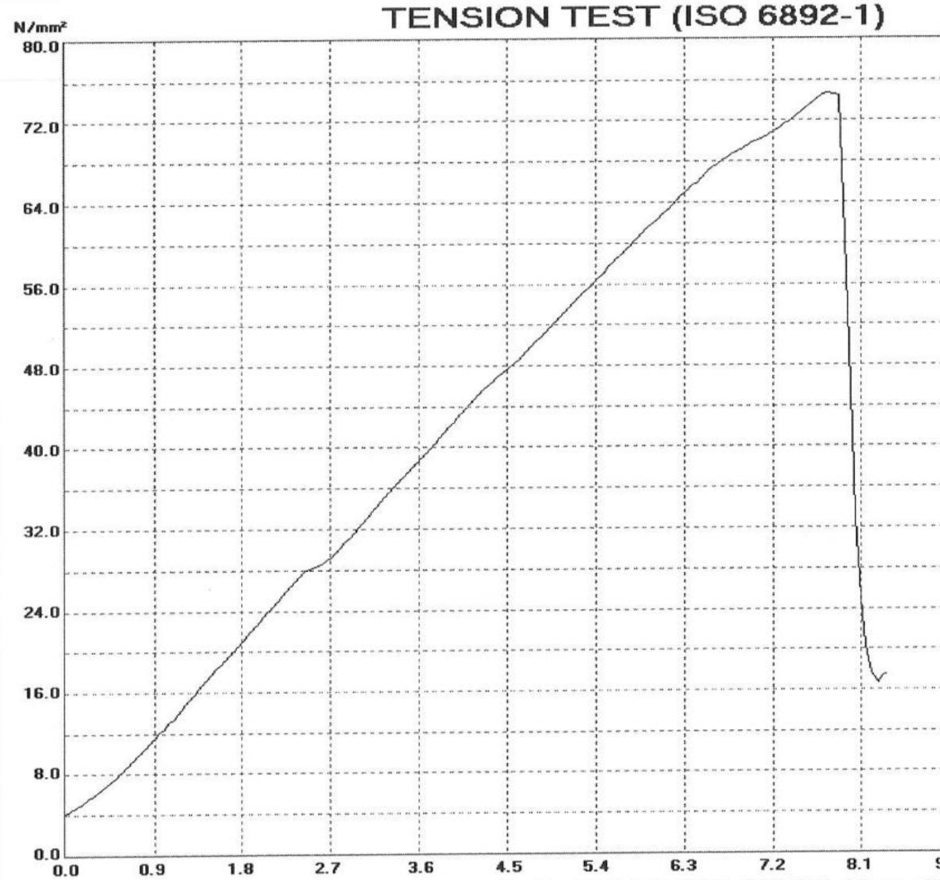
TEST DATA

Test num		11246019-A31	
Order num			
For		Mulugeta Denanto	
Reference			
Material		Composite Material(Bamboo)	
Inspector		Habtamu Mihret	
Note 1			
Note 2			
Note 3			
SPECIMEN DATA			
Specimen name			
Specimen class		Rectangle	
Thick (a)		4.30	mm
Width (b)		19.45	mm
Diam	D	0.00	mm
Gage Length	Lo	40.00	mm
Area	So	83.64	mm²
TEST RESULTS			
Force max	Fm	6.31	kN.
Tensil Stress	Rm	75.5	MPa
Yield stress UYS/(ReH)		0.0	MPa
Yield stress LYS/(ReL)		0.0	MPa
Tot Elongation	A	8.4	%
Uniform Elong	Agt	9.3	%
Yield Stress	Rp(.2%)	61.1	MPa

69.5

TENSION TEST (ISO 6892-1)

Ethiopian Conformity Assessment Enterprise



Machine PROETI: DI-CP/V2 2000 KN Serial num.: 12M9993

TEST DATA

Test num	11246019-A32
Order num	
For	Mulugeta Denanto
Reference	
Material	Composite Material(Bamboo)
Inspector	Habtamu Mihret
Note 1	
Note 2	
Note 3	

SPECIMEN DATA

Specimen name			
Specimen class		Rectangle	
Thick (a)		4.01	mm
Width (b)		19.65	mm
Diam	D	0.00	mm
Gage Length	Lo	40.00	mm
Area	So	78.80	mm²

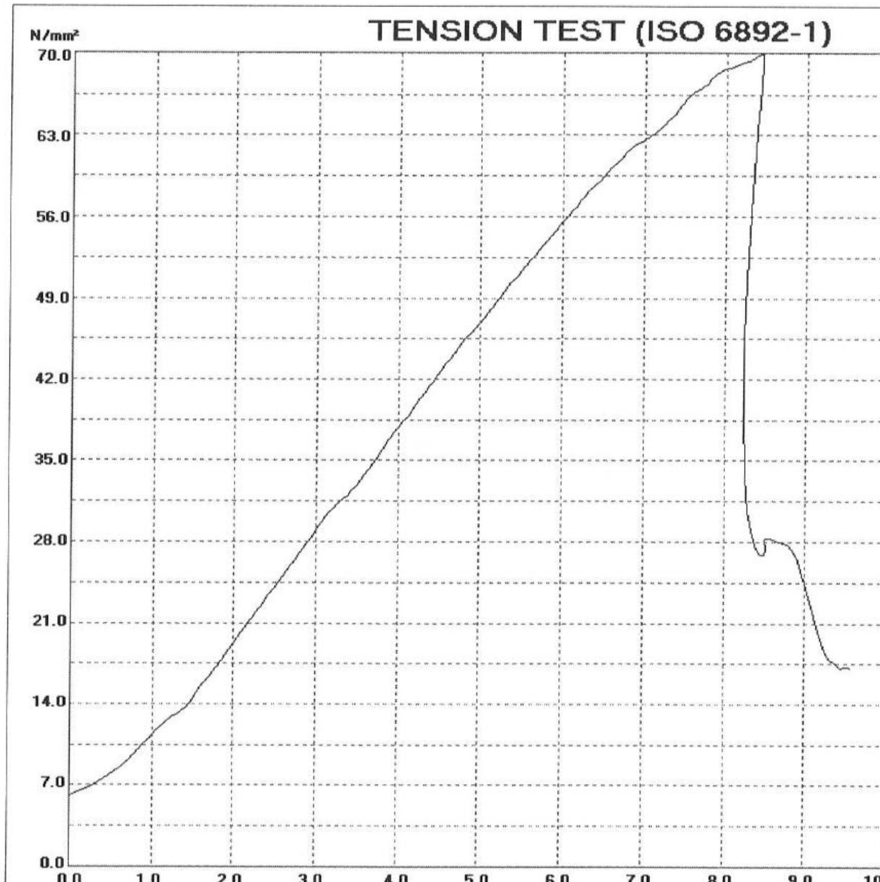
TEST RESULTS

Force max	Fm	5.89	kN.
Tensil Stress	Rm	74.7	MPa
Yield stress UYS/(ReH)		0.0	MPa
Yield stress LYS/(ReL)		0.0	MPa
Tot Elongation	A	6.7	%
Uniform Elong	Agt	7.8	%
Yield Stress	Rp(.2%)	61.0	MPa

68.4

TENSION TEST (ISO 6892-1)

ECAE Ethiopian Conformity Assessment Enterprise



TEST DATA

Test num	11246019-A33
Order num	
For	Mulugeta Denanto
Reference	
Material	Composite Material(Bamboo)
Inspector	Habtamu Mihret
Note 1	
Note 2	
Note 3	

SPECIMEN DATA

Specimen name			
Specimen class		Rectangle	
Thick (a)		4.00	mm
Width (b)		19.63	mm
Diam	D	0.00	mm
Gage Length	Lo	40.00	mm
Area	So	78.52	mm²

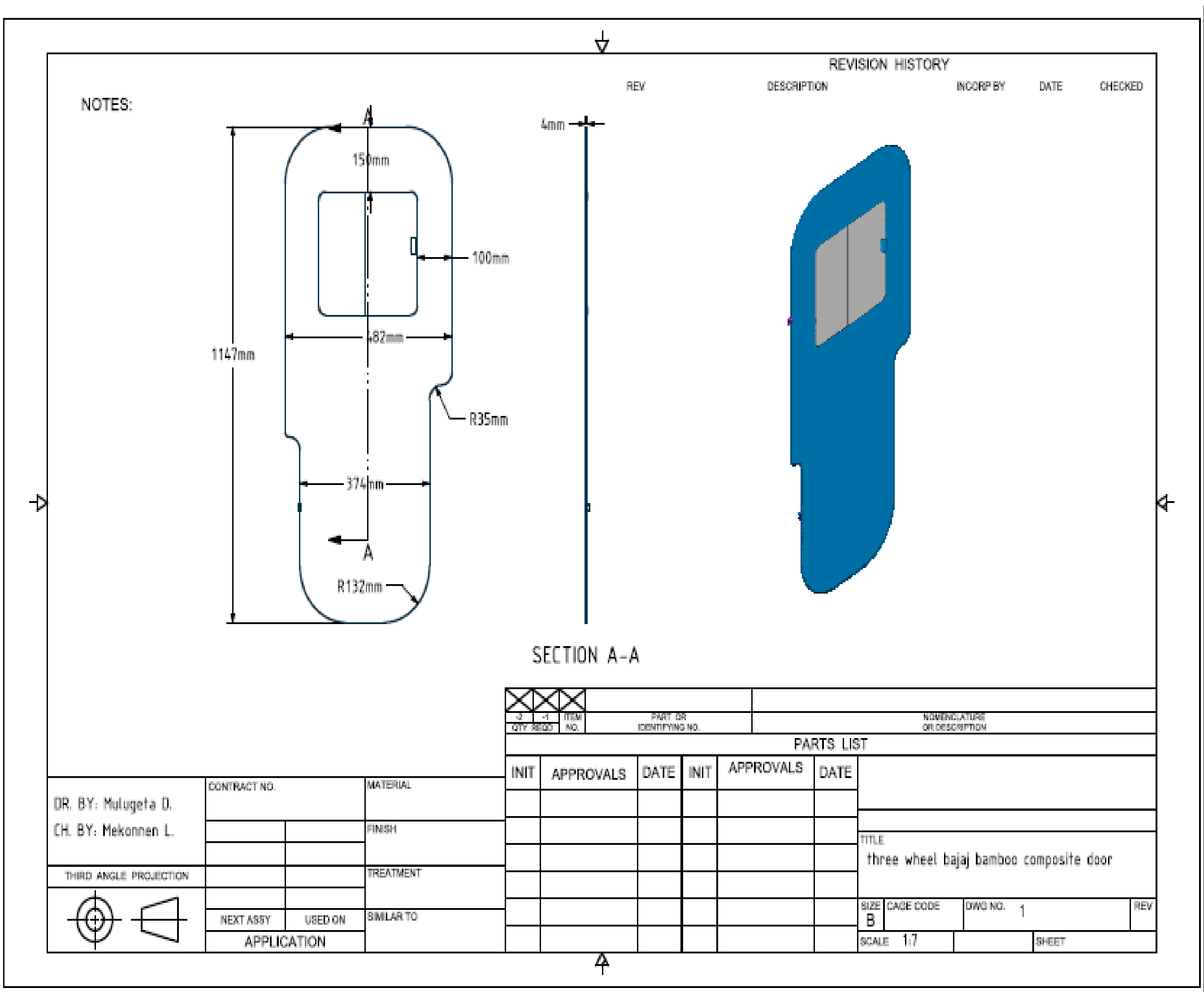
TEST RESULTS

Force max	Fm	5.50	kN.
Tensil Stress	Rm	70.0	MPa
Yield stress UYS/(ReH)		0.0	MPa
Yield stress LYS/(ReL)		0.0	MPa
Tot Elongation	A	7.8	%
Uniform Elong	Agt	8.5	%
Yield Stress	Rp(.2%)	52.2	MPa

Machine PROETI: DI-CP/V2 2000 KN Serial num.: 12M9993

63.7

D). Model drawing of three wheel Bajaj door panel



FABRICATION OF BAMBOO COMPOSITE DOOR

Preparation of sheet metal mold

A). Design of Sheet Metal Products

Figure A.1: fixing sheet metal on work bench

B). Layout Planning

Figure A.2: Lines drawn on sheet metal

C).Cutting

a). Marking sheet-metal with scissor

b). Cutting with grinding machine

Figure A.3: sheet metal cutting process

Finally figure shows below that developed door plate mold:

Figure A.4: final mold plate

4.2.1 Shaping of door from composite laminate

a) Bamboo composite mold b) cutting extra mold out-off dimension

Figure A.5: mold refinishing process

Final surface finish works includes:

a). Preparing frame stripe b). after reinforcement

Figure A.6: preparation of strengthen frame edge strips

a).front side b).Back side c). Prepared for slide window

Figure A.7: Final door products